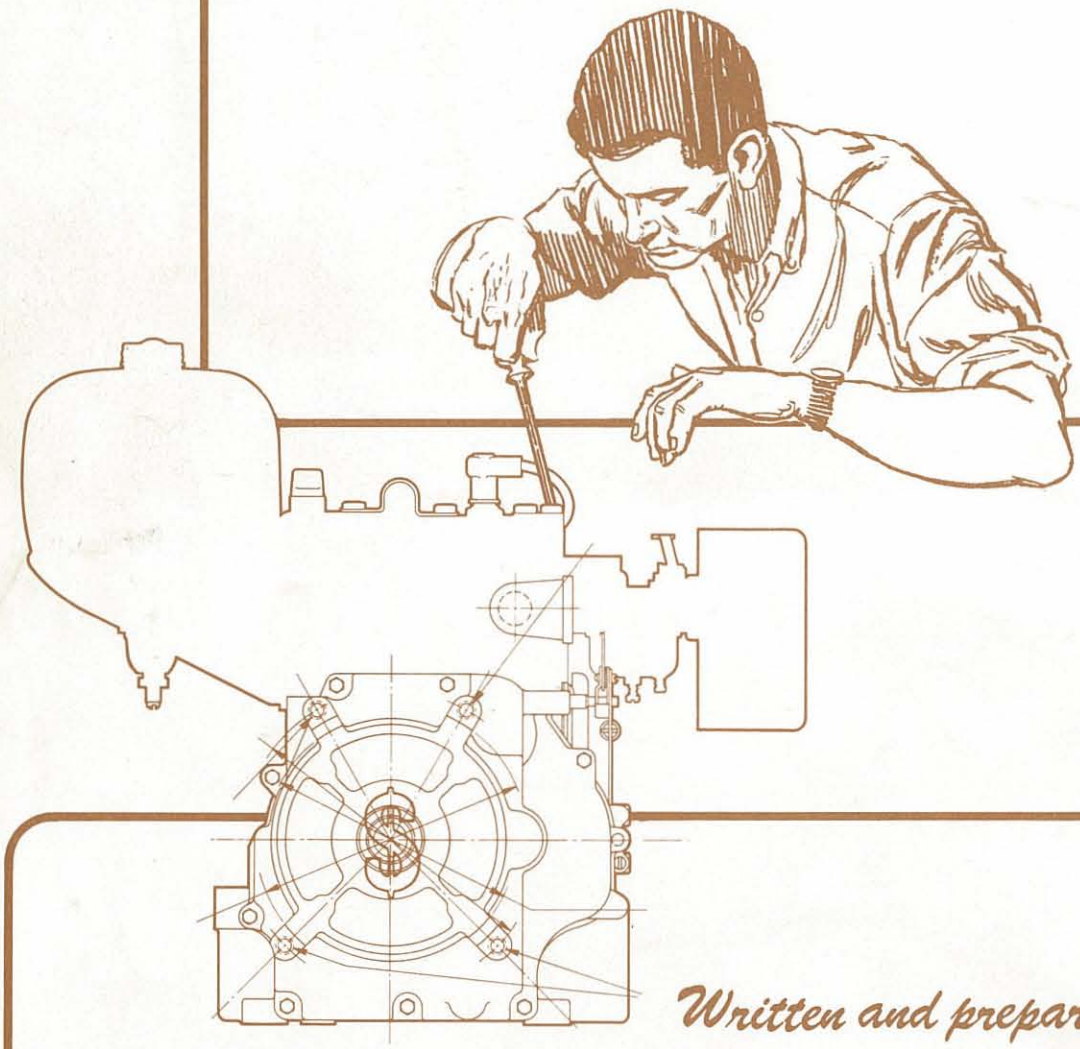
Home Study Course of –

Small Engine

Repair & Service



Written and prepared by

FOLEY-BELSAW INSTITUTE of SMALL ENGINE REPAIR

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Table Of Contents

LESSON NUMBER 1:

PRINCIPLES AND TERMS RELATING TO SIMPLE MACHINES

1 Lever
2 Inclined Plane
2 Screw
3 Wheel and Axle
3 Pulley
4 Mechanical Advantage
5 Force
5 Work
6 Energy
7 Gravity
8 Inertia
9 Momentum
9 Resistance
10 Torque
10 Friction
11 Internal Combustion Engine
12 External Combustion Engine
13 Compression
14 Expansion
14 Cycle
15 Displacement
16 Top Dead Center
17 Bore-Stroke
18 Parts of the Piston
19 Sleeve
19 Port
20 Throw-Thrust
21 Compression Ratio
22 Blow-By
23 Back-Fire
24 Reciprocating and Rotary Motion

LESSON NUMBER 2:

PRINCIPLES AND TERMS RELATING TO SMALL ENGINES

1 Engine Principles
1 Force
2 Work
2 Power
3 Horsepower
3 Brake Horsepower
4 Rated Horsepower
4 Torque
6 Measuring Torque and Horsepower
6 Dynamometers
6 Engine Horsepower Variations
7 Basic Engine Principles
9 Engine Applications
10 Distinguishing Features of Small Engines
10 Vertical Crankshaft Engines
11 Horizontal Crankshaft Engines
12 Multi-Purpose Crankshaft Engines
12 Problems with Small Engines
12 Engine Abuse

LESSON NUMBER 3:

INTRODUCTION TO SMALL ENGINE SERVICE

1 Care and Operation of Small Engines
1 Common Causes of Operating Troubles
1 Engine Identification
2 Other Nameplate Instructions
2 User Servicing of Small Engines
2 2-Cycle and 4-Cycle Identification
3 How Small Engines are Cooled
4 Conduction and Convection
5 Importance of Cleaning
5 Cleaning Tools and Materials
6 Small Engine Operation

LESSON NUMBER 4:

TWO AND FOUR CYCLE BASIC PRINCIPLES

1 4-Cycle Basic Operation
2 2-Cycle Basic Operation
3 Cylinder Piston and Rod Assembly
4 Piston Assembly
4 Types of Pistons
5 Rings
10 Rod Assembly
11 Checking For Proper Operation

LESSON NUMBER 5:

AIR CLEANERS AND FILTERS

1 2-Cycle and 4-Cycle Similarities
1 Fuel System
1 Cleaners
2 Oil Bath Air Cleaners
3 Oiled Filters
4 Dry Filters
4 Importance of Air Cleaner Service
5 Air Cleaner Service Schedules
5 Servicing Air Cleaners
16 Servicing Fuel Strainers

LESSON NUMBER 6:

CARBURETION

1 Basic Fuel System
2 Carburetor Functions
2 Carburetion
2 Fuel-Air Mixture Ratio
2 Fuel Tank Venting
3 Carburetor Principles
3 Types of Carburetors
4 The Venturi
5 Throttle Valve
6 Choke Valve
7 Idle Mixture Adjustment
8 High Speed Mixture Adjustment
8 Jet Adjustments
8 Types of Fuel Systems
8 Gravity Feed System
9 Suction Lift System
10 Mechanical Feed Systems

LESSON NUMBER 7:

FLOAT CARBURETOR PRINCIPLE

1 Simple Float Carburetor
2 Float Carburetor With Constant Load
3 Provisions for Sudden Load
4 Provisions for Idling
7 Pressure Equalization
8 Air Passage Instruction
8 Welch Plug
10 Choke
11 Automatic Chokes
12 Primer

LESSON NUMBER 8:

DRAWINGS, PART NUMBERS AND FLOAT CARBURETOR REPAIR

1 Exploded View Drawings
5 Part Numbers and Models
5 Related Drawings
9 Float Carburetor Repair

LESSON NUMBER 9:

DIAPHRAGM, SUCTION LIFT AND AUTOMAGIC CARBURETORS

1 Diaphragm Carburetor
3 Diaphragm Carburetor Repair
4 Suction Lift Carburetor
6 Suction Lift Carburetor Repair
6 Automagic Carburetor

LESSON NUMBER 10:

CARBURETOR CLEANING AND ADJUSTMENTS

1 Carburetor Linkage
2 Cleaning Carburetors
2 Installing the Carburetor
3 Carburetor Adjustments
5 Choke Adjustments

LESSON NUMBER 11:

TWO AND FOUR CYCLE FUEL

1 Fuel
1 Octane Rating
2 Summer and Winter Fuels
2 Storing Fuel
3 2-Cycle Fuel
5 Fuel Delivery System

LESSON NUMBER 12:

FUEL PUMPS

1 Fuel Pump
1 Mechanical Fuel Pump
3 Differential Pressure Fuel Pump
5 Checking Fuel Pumps for Operation

LESSON NUMBER 13:

GOVERNORS

1 Governor Functions
2 Types of Governors
2 Air-Vane Governors
4 Centrifugal Force
5 Centrifugal Governor
7 Governor Adjustments
9 Engine Speeds
10 Engine Speed and Applications

LESSON NUMBER 14:

MANUAL STARTERS

1 Starters
1 Starter Functions
2 Rope Replacement
2 Rope-Rewind Starters
6 Rewind Rope Replacement
10 Broken Rope

LESSON NUMBER 15:

SPRING STARTERS

1 Wind up Starters
5 Gear Ratio
7 Recoil Spring Replacement

LESSON NUMBER 16:

TROUBLE SHOOTING STARTERS

1 Kick Starters
2 Trouble Shooting Manual Starters
4 Trouble Shooting Rope Rewind Starters
6 Trouble Shooting Wind Up Starters
8 Trouble Shooting Kick Starters

LESSON NUMBER 17:

ELECTRICITY

1 Fundamentals of Electricity
3 Conductors
3 Insulators
4 Ampere
4 Volts
4 Resistance, Resistors and Ohms
5 Electrical Circuits
6 Series Circuit
8 Short Circuit
9 Parallel Circuit
11 Series-Parallel Circuits
11 Alternating Current
13 Electromagnetism

LESSON NUMBER 18:

ELECTRIC STARTERS

1 Alternating Current Electric Starters
1 Direct Current Starters
2 Electric Starter Basic Components
2 Starter Fundamentals
3 Servicing Starters and Generators
3 Bearing Check
3 Brush Check
6 Commutator Check
7 Seating New Brushes

LESSON NUMBER 19:

ELECTRIC STARTER DRIVES

1 Electric Starter Drives
1 Bendix Drive
3 Cone Friction Clutch Drive
4 Split Pulley Clutch Drive

LESSON NUMBER 20:

BATTERY AND STARTER CIRCUITS

1 Basic Starting Circuit Wiring
1 Starter-Generator Circuit Wiring
2 Starter-Generator With Regulator
3 Trouble Shooting DC Starter Circuits
6 Trouble Shooting DC Generator Circuits
6 Low Amperage Reading
7 High Amperage Reading
7 Zero Amperage Reading
8 Solenoid Switch
9 Alternators and Rectifiers

LESSON NUMBER 21:

BATTERIES

1 Lead-Acid Cell
3 Lead-Acid Batteries
3 Lead-Acid Battery Ratings
4 Battery Liquid
6 Hydrometer Test
9 Voltmeter Test
10 Battery Maintenance
13 Nickel Cadmium Batteries

LESSON NUMBER 22:

MAGNETO PRINCIPLES

1 Ignition Theory
1 Magneto Ignition System
3 Principles of Magnetism
5 Transformer Principles
6 Magneto Fundamentals
7 Fly Wheel Magneto
11 Stopping Magneto Equipped Engines

LESSON NUMBER 23:

ELECTRICAL DISTRIBUTION AND SOLID STATE IGNITION

1 Condenser
3 Three Steps of the Magneto
5 Distributor
7 Solid State Ignition
10 Trouble Shooting Solid State Ignition

LESSON NUMBER 24:

SPARK PLUGS

1 Parts of the Spark Plug
3 Types of Spark Plugs
5 Hot Plugs
6 Cold Plugs
7 Plug Length
9 Plug Thread and Reach
10 Spark Plug Inspection and Service
12 Cleaning Spark Plugs
13 Spark Plug Maintenance
14 Spark Plug Wear
15 Spark Plug Cap
16 Installing Spark Plugs
17 New Spark Plugs

LESSON NUMBER 25:

THE MAGNETO AND FLY WHEEL

1 Magneto Maintenance
2 Checking Magneto Operation
3 Fly Wheel Removal
8 Fly Wheel Puller
9 Fly Wheel Inspection

LESSON NUMBER 26:

BREAKER POINTS

1 Types of Breaker Points
6 Breaker Point Assembly Inspection
7 Breaker Point Check

LESSON NUMBER 27:

IGNITION SERVICE

1 Replacing Points
3 Checking the Condenser
5 Checking Magneto Coil
7 Stator Plate and Coil Service

LESSON NUMBER 28:

MAGNETO TIMING

1 Timing the Magneto to the Engine
7 Top Dead Center Timing Tool
8 Armature Air Gap
8 Magnet Strength
9 Breaker Point and Cam Functions
13 Battery Ignition Systems

LESSON NUMBER 29:

TWO AND FOUR CYCLE VALVE ACTION

1 2-Cycle Stroke
3 2-Cycle Valve Action
7 4-Cycle Stroke
7 4-Cycle Valve Action

LESSON NUMBER 30:

FOUR CYCLE VALVE ASSEMBLY

1 4-Cycle Valve Identification
2 Parts of the Valve
2 Parts of the Valve Assembly
4 4-Cycle Valve Damage
6 4-Cycle Valve Operation

LESSON NUMBER 31:

FOUR CYCLE TIMING AND COMPRESSION TEST

1 4-Cycle Valve Timing
2 Valve and Cam Functions
5 Valve Compression Test
8 Compression Gauge
9 Valve Tappet Clearance
12 Tappet Clearance Design

LESSON NUMBER 32:

CYLINDER HEAD AND VALVES

1 Removing Cylinder Head
3 Cleaning Cylinder Heads
3 Cleaning Cylinder Blocks
4 Removing Valves
5 Inspecting Valve Assemblies
7 Valve Condition and Cause
8 Valve Guides

LESSON NUMBER 33:

VALVE REPAIR

1 Grinding Valves
2 Valve Specifications
2 Grinding Valve Seats
4 Replaceable Valve Seats
5 Lapping Valves
7 Valve Tappet Adjustment
8 Installing Cylinder Heads

LESSON NUMBER 34:

PISTON AND ROD REMOVAL
1 Removing 4-cycle Piston and Rod Assemblies
6 Removing 2-cycle Piston and Rod Assemblies
8 Piston and Ring Inspection
9 Rod and Bearing Inspection

LESSON NUMBER 35:

INSTALLING ROD BEARINGS, RINGS AND PIN
1 Rod and Wrist Pin Bearing
2 Piston and Rod Disassembly
4 Installing Rings and Pin
6 Installing Piston and Rod
8 Cylinder Inspection

LESSON NUMBER 36:

MAJOR OVERHAUL AND SHORT BLOCK
1 Cylinder Reboring
2 4-cycle Camshaft Assembly
8 Crankshaft Assemblies
9 Checking Crankshaft Condition
13 Crankshaft Oil Seal Replacement
15 Crankshaft Removal
17 Crankshaft Bearings
18 Short Block

LESSON NUMBER 37:

LUBRICATION AND BREATHERS
1 Crankcase Breathers
4 Lubrication
6 4-cycle Lubrication Systems
8 Checking Oil and Pumps

LESSON NUMBER 38:

PARTS CATALOG AND TROUBLE SHOOTING
1 Parts Catalog Reading
4 Microfiche
4 Brand Unit Identification
5 Trouble Shooting
Repair Parts Inventory

LESSON NUMBER 39:

ENGINE DISASSEMBLY
1 Introduction
2 Before Operation Check
3 Engine Service Check
4 Preparing Engine for Disassembly
5 Fuel Tank and Blower Housing Removal
6 Carburetor Control Plate Removal
7 Carburetor Removal
8 Flywheel Nut Removal
8 Flywheel Removal
9 Ignition Removal
10 Head and Spark Plug Removal
11 Valve Cover Removal
12 Valve Removal
13 Crankcase Cover Removal
14 Camshaft Removal
15 Piston and Crankshaft Removal
16 Disassembly Layout

LESSON NUMBER 40:

ENGINE ASSEMBLY
1 Crankshaft Installation
2 Piston and Rod Assembly
3 Rod Cap Assembly
4 Valve Lifter Assembly
5 Camshaft Assembly
6 Cover Plate Assembly
7 Installing Valves
8 Valve Spring and Keeper Assembly
9 Valve Cover and Breather Assembly
10 Cylinder Head Assembly
11 Breaker Cam Assembly
12 Magneto Assembly
13 Ignition Point Assembly
14 Fly Wheel and Starter Cup Assembly
15 Muffler Assembly

LESSON NUMBER 41:

CARBURETOR DISASSEMBLY AND REASSEMBLY
1 Air Cleaner Disassembly
2 Carburetor Disassembly
3 Removing Speed Adjustment Screws
4 Fuel Bowl Removal
4 Float Removal
5 Installing Float and Bowl
6 Installing Jets and Control Shafts
7 Installing Governor Control
8 Installing Carburetor Control Plate
9 Installing Air Shroud
10 Installing Blower Housing

LESSON NUMBER 42:

OPERATING A SERVICE BUSINESS
1 Service Charge
2 Repair Tags
4 Inventory Control
6 Parts Storage
7 Be Fair
7 Be Helpful

7 Extra Service
8 Success and Failure
8 Layout for Efficiency
8 Use Modern Tools
8 Storage
9 Work Area
9 Advertising
9 Your Best Advertising Is A Satisfied Customer
9 Direct Mail Advertising
10 Phone Book Advertising
10 Newspaper Advertising
10 Signs and Displays
10 Expanding Your Business With Other Services

INTRODUCTION

Welcome to the Foley-Belsaw Institute. You have made an important decision. You are going to learn one of the most interesting rapidly growing repair services in this country. This training will allow you to start your own profitable full or part-time repair business in an expanding field with a shortage of qualified repairmen.

The Engine Service Association, a national organization devoted to small engine service, estimates that there are over 45,000,000 small engines in service today and new engines are being built at a rate in excess of 1,000,000 per month. The small engine industry is one of the fastest growing industries in this country today. In the past 22 years it has literally grown by over 2,400 percent. Almost all of this vast number of engines are under 20 horsepower and are used to power a wide range of products such as lawnmowers, chain saws, riding mowers, tractors, snow-blowers, edgers, roto-tillers, golf carts, generators, go-karts, motorcycles, and an almost endless number of special applications.

Most of these engines are built by a small handful of manufacturers who supply them to the people who produce the various power-driven tools and equipment. By far the largest number of small engines produced each year are in the 3.5 H.P. range used on most rotary lawnmowers.

Obviously such growth has created a tremendous demand for trained servicemen. In fact, it is a demand that gets greater every year. And, contrary to many businesses that are recession prone, the small engine service business has yet to reach its full potential.

For the man interested in having a profitable, stable business of his own there are few business situations that offer more opportunity.

Best of all, no previous experience is required. You don't need to be a college graduate, an expert mechanic or even a high school graduate. If you can read and understand this short introduction and enjoy working with your hands, you should be able to complete the course without difficulty.

The course is fully illustrated and written in easy to understand language. It is ideal for men from high school age on up who are interested in having a profitable, part-time or full-time trade.

It is also useful for the shop mechanic who wants to supplement his small engine knowledge and build a valuable reference library.

By enrolling the Foley-Belsaw Institute Course of Small Engine Servicing, you have taken the first step that will enable you to increase your earnings and develop your reputation as a specialist in your community.

When you have completed your training, you should have a good knowledge of how to repair and service a wide variety of engines up to 20 H.P. You will be able to identify engine problems quickly, determine the best method of correcting them (repair, adjustment or replacement) and you will know which tools and equipment to use to do the most efficient job. In fact, you will already have many of these tools since they come to you with your training.

In addition, a very important part of the course tells you how to get business, how much to charge, how to get free advertising, where to get parts and supplies, how to organize your shop and much, much more.

When you have successfully completed the Basic lessons, you will receive a handsome, framed diploma in "Basic Small Engine Repair." Then, when you have successfully completed the Advanced section, you will receive a second diploma in "Advanced Small Engine Repair". Display these proudly. Your customers will be confident they are dealing with a true professional.

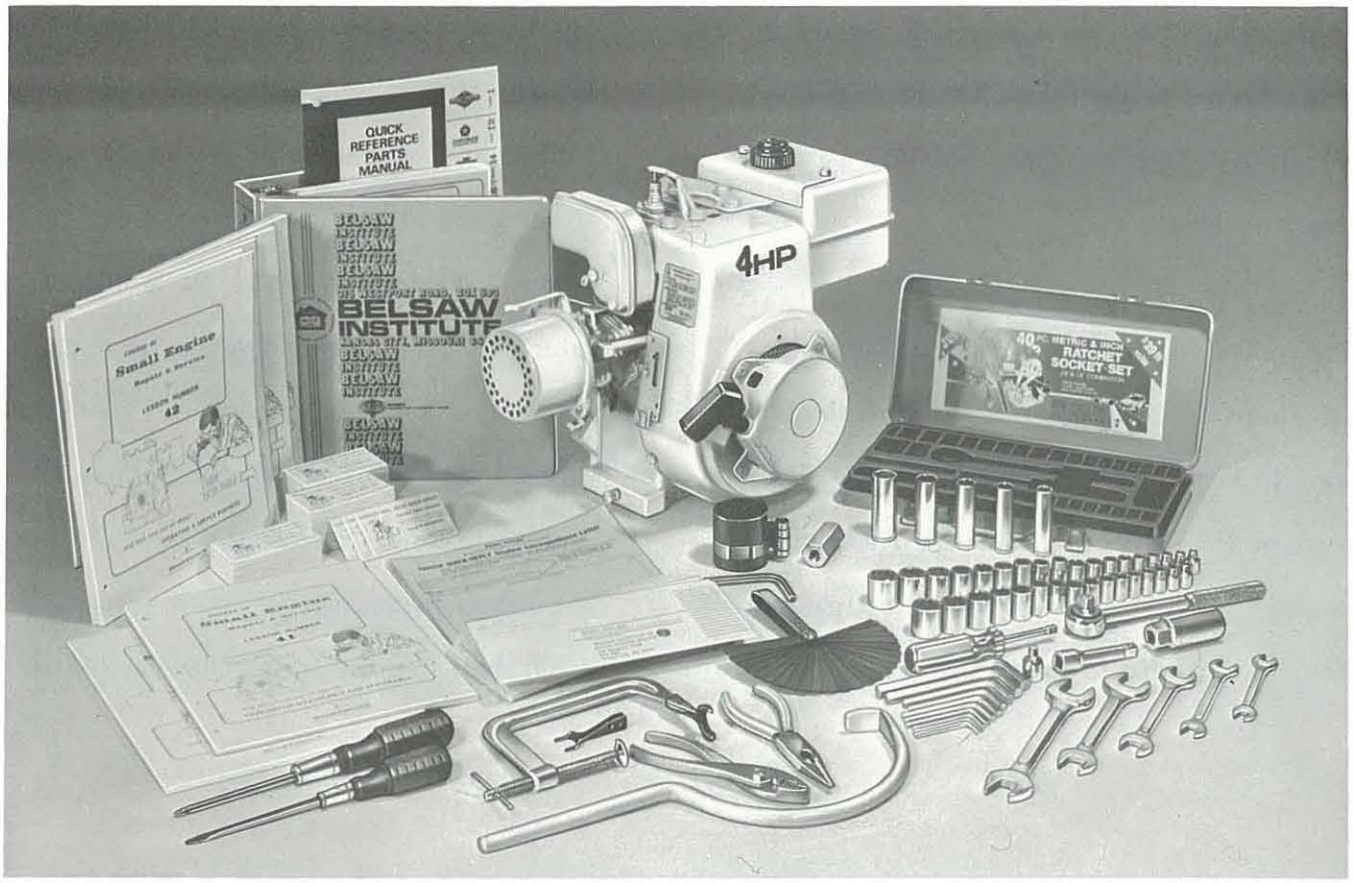
As you progress through this course you will receive written examinations with your lessons. These examinations will contain questions concerning the lesson you have just completed and some will be related to past lessons. Return these as soon as you have completed the lesson. Your instructor will grade and evaluate each question and return the graded exam so you can see your progress.

The complete course contains 42 lessons, each with either a working project or examination. For your convenience, a pre-addressed, envelope is provided for each examination to be sent in for grading.

In addition, a supply of special "Quick Reply" forms are included for any questions you may have concerning the lesson material (please do not write questions on the examination sheets).

As a part of your training, you will also receive special tools and materials. This is full-size, regulation equipment that should serve you well not only in your studies, but through-out your career.

Listed below are the special tools and study aids you will receive as a part of your training:



Forty piece socket wrench set and carrying kit

Eleven piece Allen wrench set and holder

Five piece deep drive socket wrench set

Standard pliers

Needle-nose pliers

Phillips-head screwdriver

Slot-head screwdriver

Five piece set of open end wrenches

Flywheel holder

Impact nut

Ring compressor

Valve Spring compressor

Ignition feeler gauge

Complete, fully assembled 4 H.P. horizontal shaft engine.

Small engine parts manual (Quick Reference Manual).

With lesson Number 11 you will receive your basic engine tool set that you can use to begin working. Later during the course you will receive the special engine tools needed for the various assignments and for complete disassembly of the engine you will receive with Lesson 39. You will completely disassemble this engine and then put it back together. This will be your engine to keep.

The course you are about to begin is a working "hands-on" training program. One of the best ways to learn a subject is to "learn by doing". Most of these lessons can be used as a work project so that you can learn by actually doing. You are told what to do, how to do it and when to do it. All phases of small engines are taken up step by step so you can see how they all fit together to make the complete engine run.

Your instructor will be glad to give you any individual help concerning your lessons. Since this is a step by step instruction course please confine your questions to the lesson you are working on. It would not be fair to you to give advance information that you will learn in future lessons. This would lead to confusion.

Before you begin, be sure to read the "Study Guide." Then go on to lesson Number 1 and study it carefully. It may seem quite basic, but as you go through the course you will find it will apply to many of the following lessons.

Schedule Your Time

Successful students make regular and systematic study a habit. Sounds hard? Not really. The trick is not in how long you study, but in how *regularly* you study. Setting aside a short period each day or even each week for study will help you finish much faster than studying long hours on a haphazard basis.

So make a schedule for yourself and stick to it. Don't wait long periods between study sessions. Short but regular study periods are best. That way, your mind will stay fresh and alert.

We suggest that you try to study at least one half hour each day. If possible, study at the same time each day. Before long, this routine will be a habit.

Take Frequent Breaks

If you prefer to study longer periods each session, be sure to take a break at regular intervals. Get up, stretch your muscles, walk around and forget about your studies for a bit.

By following these suggestions, you will remain fresh and alert and able to gain the most from your course. Remember, the knowledge you gain will be worth money to you when you finish. The more you learn, the more you will be able to make.

Your Study and Work Area

Try to find an area where you can be by yourself – your own room, basement, workshop, garage, corner, or similar place.

The space you select should have proper ventilation, good lighting, power outlets, enough working room and, if possible, it should be a quiet place where you can concentrate.

You should arrange your work area so that your equipment and lessons are organized and within easy reach. This way, you will not lose valuable time looking for materials during your study period.

For proper lighting, we recommend using at least a 100 watt bulb no more than 6 or 8 feet from your work surface.

Ventilation

Ventilation is extremely important when working with gasoline engines. If you are working in an air-conditioned area where the air is re-circulated, keep at least one window open or turn the air-conditioner to the "Exhaust" setting.

Since you will be working in the presence of gasoline, be sure to follow recommended safety rules for storing and using this product. Make *very sure* that your work area is a safe distance from pilot lights on water heaters, stoves, heaters, stoves, furnaces, gas air-conditioners, etc.

We strongly recommend that engines be started only outside and that engine gas tanks be filled or drained in an outside area!

Work Surface

All you should need in the way of furniture for your work area is a chair or stool and a work bench. If you do not have a work bench, an old table or desk will be fine. It is also possible to use a large piece of 3/4" plywood laid across two sawhorses.

How to Make Learning Easy

To get the most from a lesson, first read through it to get a general idea of what it covers. Then, go back and read it again – this time, read it slowly, topic – by – topic.

As you read, don't worry about "memorizing" facts or wording. All that you need to do is form an *understanding* of the principle or procedure involved. Anyone can "memorize", but if you know *how* and *why* something works, you will never forget it.

If, after carefully studying a lesson, you still have any doubts left, then write your instructor at Belsaw for help and guidance.

Your course has been designed so that you will be kept informed on your grades and progress every step of the way. You should always have enough lessons and projects on hand to keep busy.

Thus, you are never held back by slower students or forced to work faster than your time allows.

If, after you begin sending in lessons, you find you can study faster than the schedule calls for, then it means you have the ability to finish your Course much sooner than the average.

Since the shipping schedule is coordinated both with your grade record and with tuition payments, you need only to complete and send in your examinations and to remit advance payments for the additional lessons you wish to complete.

How Your Lessons Are Graded

We want you to make the very best grades possible because the more you learn, the more you will profit from your training.

To do this, you should study each lesson to the best of your ability. And remember, if you have any doubt regarding an examination question, go back immediately and review the lesson on the subject in question before answering.

If you have answered a question correctly, your Instructor will not mark the examination. However, if it is incorrect, your instructor will indicate this and, if necessary, will give you an explanation. Don't forget, you can often learn more from your mistakes than you can from your successes!

Your examinations are graded on a percentage basis as follows:

90 – 100 = A (Excellent)

80 – 89 = B (Very Good)

70 – 79 = C (Good)

60 – 69 = D (Passing)

Your Diploma will be awarded on the basis of your average grade level for the entire course.

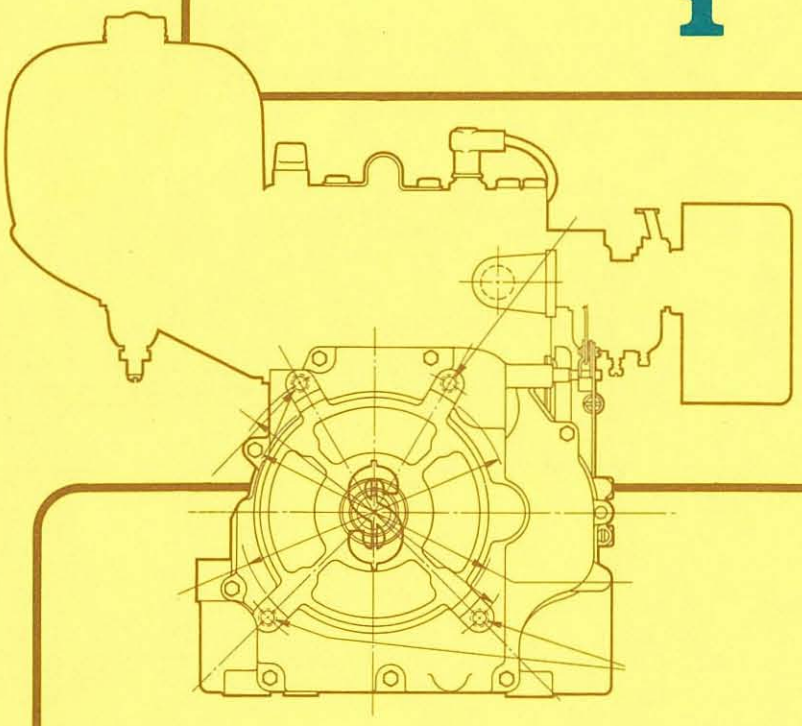
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

1



TURN THIS PAGE

...and let's find out all about --

PRINCIPLES AND TERMS
RELATING TO SIMPLE MACHINES

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PRINCIPLES AND TERMS RELATING TO SIMPLE MACHINES

There are many technical terms used in describing the parts and functions of small engines. Before we go into the basic principles of small engine operation, it will be necessary to become familiar with some of these terms as they apply to things around us in everyday life. All of these terms will have a definite relationship in one way or another to small engine operation. There are a number of basic principles, one or more of which can be applied to all machines and mechanical applications.

LEVER

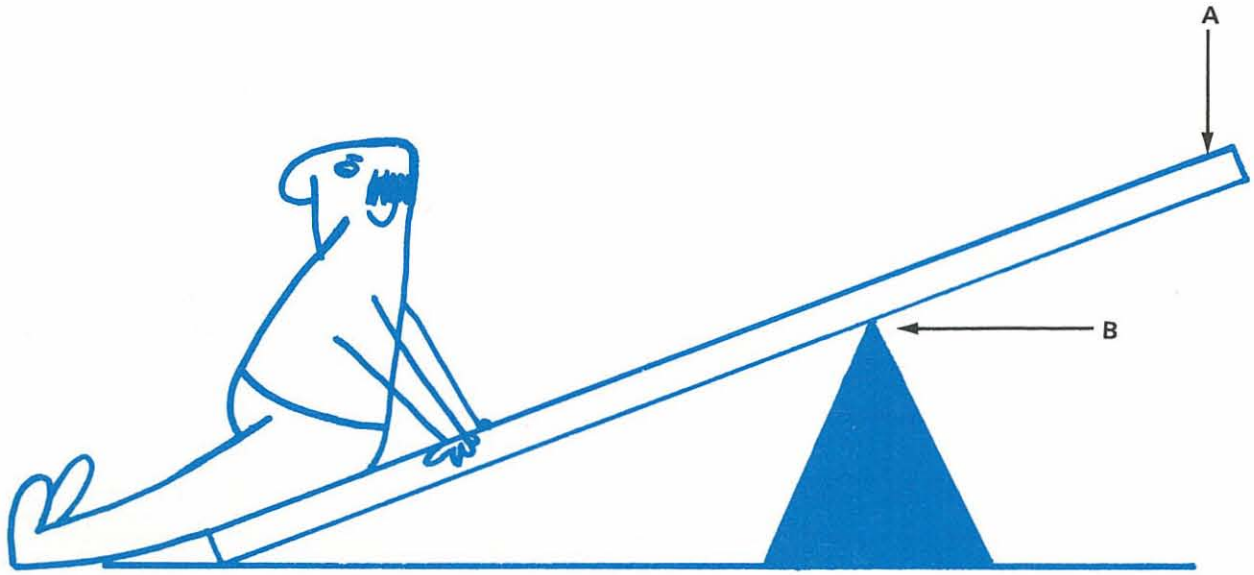


Figure 1A

LEVER

The lever was probably the first mechanical application discovered by man. The lever is a simple method of increasing the amount of force that can be exerted on an object. Figure 1A shows the two parts of the lever principle. The lever is shown at A and the fulcrum at B. When using this principle a very heavy load can be lifted or moved with very little effort. It may be impossible for a person to lift a thousand pounds but, with the help of a lever the proper length and a fulcrum properly placed, this work could be easily accomplished.

INCLINED PLANE

Another principle is shown in Figure 2A. The inclined plane is similar in some ways to the lever. A load, as shown at A, can easily be moved from point B to point C by rolling it up an inclined slope. If this load had a weight of several hundred pounds it would be impossible to lift it from point D to point C. By rolling or pushing it up the slope from point B to point C, this work could easily be accomplished.

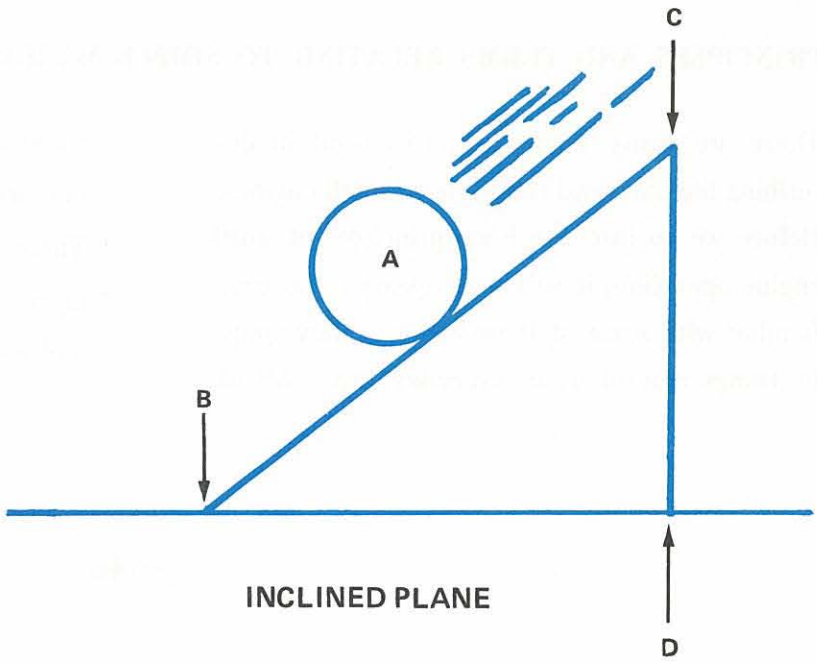
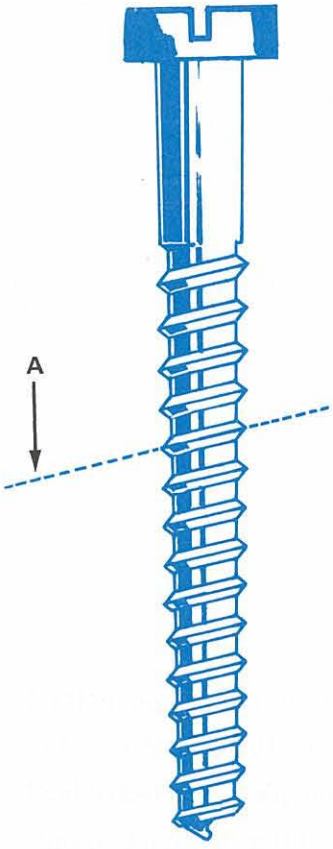


Figure 2A



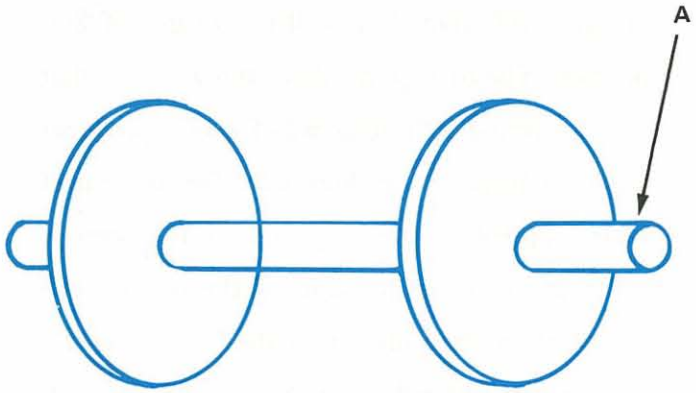
SCREW

Figure 3A

SCREW

The screw, shown in Figure 3A, operates on somewhat the same principle as the lever and the inclined plane. If you will study these three drawings carefully, you will see there are several things they have in common. All three use the principle of either moving the load at an angle so that the applied force or effort must be moved a greater distance to move the load. The screw angle, shown at A, must move a long distance in order to raise or lower it. A common application of the screw is the car jack which allows you to raise a very heavy load with very little effort.

WHEEL AND AXLE



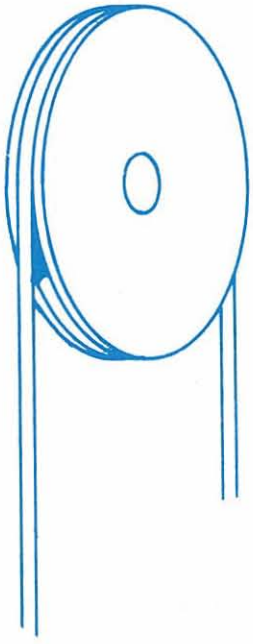
WHEEL AND AXLE

Figure 4A

The wheel and axle shown in Figure 4A, is more evident in most mechanical applications than most of the others. It transmits weight or load into rotary motion. A great amount of weight can be applied to point A on the axle and an object can be easily moved. The weight on the axle is transmitted to the wheel and converted into rotary motion for movement.

PULLEY

The pulley shown in Figure 5A, permits moving weight that could be accomplished by lifting or pushing. By using different arrangements of pulleys, the lifting or pulling power can be increased several hundred times. A common example of this principle is the block and tackle used to lift heavy loads. Most all automotive repair shops have a block and tackle they use for lifting engines from automobiles. This allows one man to lift the entire engine, weighing several hundred pounds, out of the car.



PULLEY

Figure 5A

MECHANICAL ADVANTAGE

The five basic principles of the lever, inclined plane, screw, pulley and the wheel and axle are the basic actions that allow us to multiply an applied force. The number of times a force is multiplied is called the mechanical advantage. Figure 6A shows a typical example of mechanical advantage. It would be very difficult to lift a weight of 300 pounds straight up but, with the help of a lever, we could use the mechanical advantage of the fulcrum. With the fulcrum located as shown, we could have an applied force of only 100 pounds and lift a weight of 300 pounds. The basic principle of this action is that a force exerted at the long end of a lever produces a greater force at the short end. The amount of force applied at the long end of the lever is determined by the location of the fulcrum. If the fulcrum were moved to the left , it would take greater applied force to move the load. If it were moved closer to the load it would take less applied force.

MECHANICAL ADVANTAGE

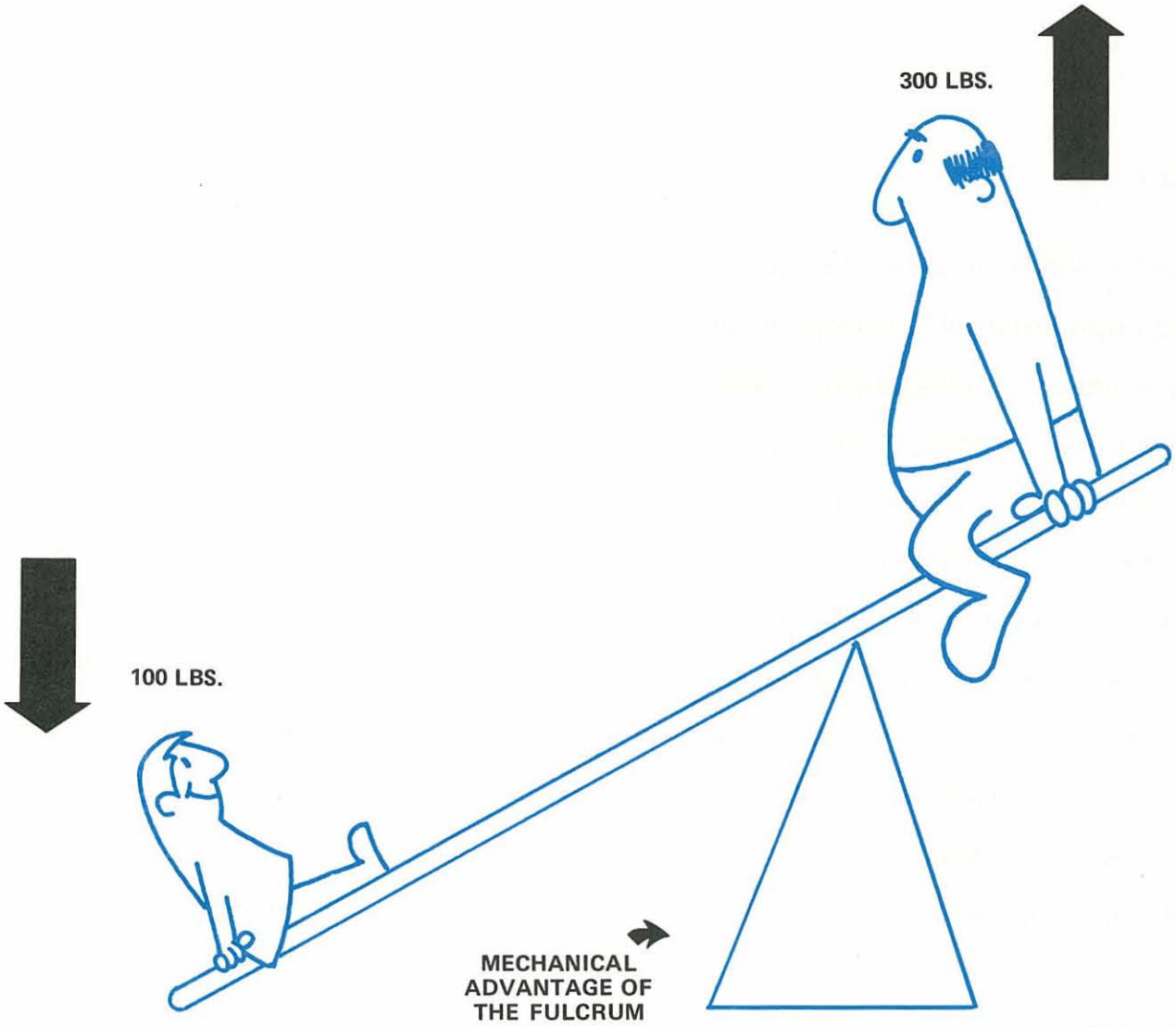


Figure 6A

FORCE IS A PUSH OR PULL.

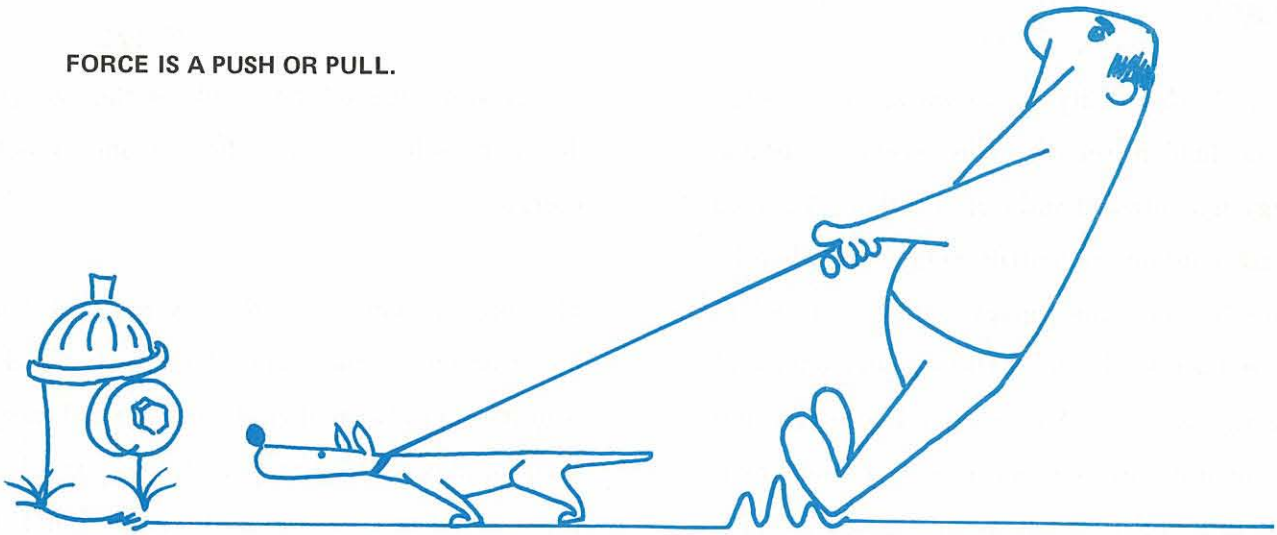
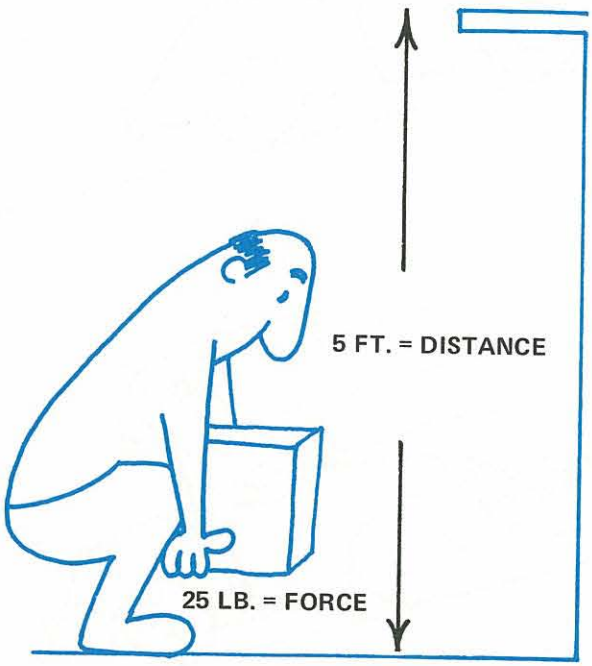


Figure 7A

FORCE

A force as shown in Figure 7A, is a push or pull exerted on an object in an attempt to change its condition. When a gas or air is heated it expands and occupies more space. Gravity has a pull to bring things closer to the center of the earth. Magnetic poles attract or repel each other. These are all forces. They all tend to change the state or condition of an object from its present state to another.

WORK



WORK = FORCE x DISTANCE

Figure 8A

WORK

Work is the movement of an object or weight through a distance. Moving an object from one place to another requires work. Figure 8A shows a typical example of work. Lifting a box or weight from the floor and placing it on a shelf is work. The height of the shelf and the weight of the box determine the amount of work accomplished. From this we get the formula of:

WORK = FORCE X DISTANCE

If we lift a 25 pound box to a shelf 5 feet from the floor, work has been accomplished. Work is expressed in foot pounds (ft-lbs). Moving a 25 pound box to a shelf 5 foot high would require 125 foot pounds of work.

ENERGY

Energy is the ability to do work. This energy can be held in reserve or in action. Potential energy is contained and not in action. A person at rest contains potential energy and when he begins to move this energy is then changed to kinetic energy. Figure 9A shows an example of energy. The car at A is tied to a tree and cannot roll down hill as long as it is tied. The energy is there to be released but it is in a potential state. If the car were released, as shown at B, the car would roll down the hill. The stored potential energy has been released and, as the car rolls down the hill, the energy then becomes kinetic energy.

The fire cracker is another example of both potential and kinetic energy. When a fire cracker is in its natural state it contains potential energy that is stored. When the firecracker fuse is lighted it will cause an explosion. This explosion is the release of potential energy. It is then converted into kinetic energy.

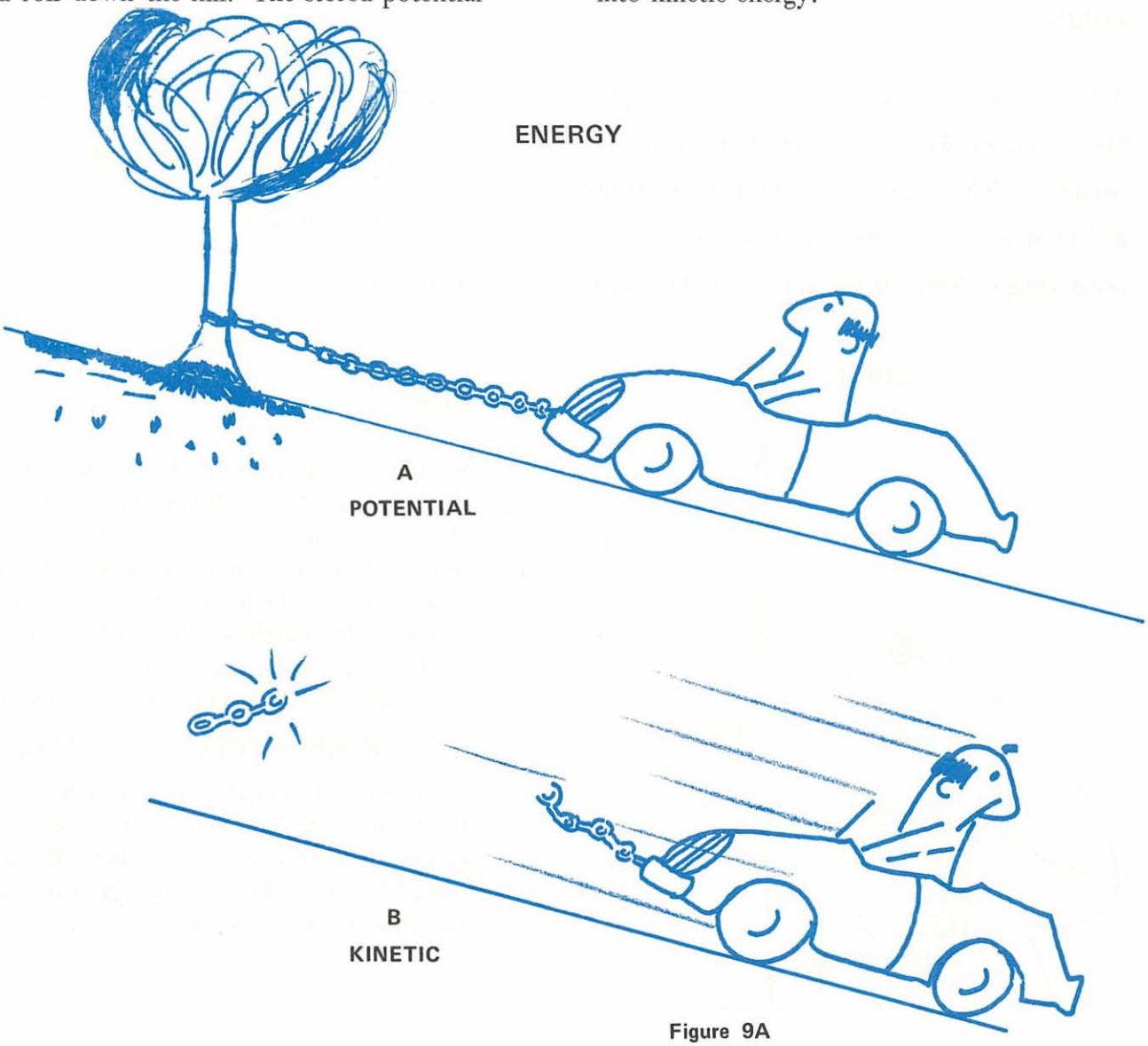


Figure 9A

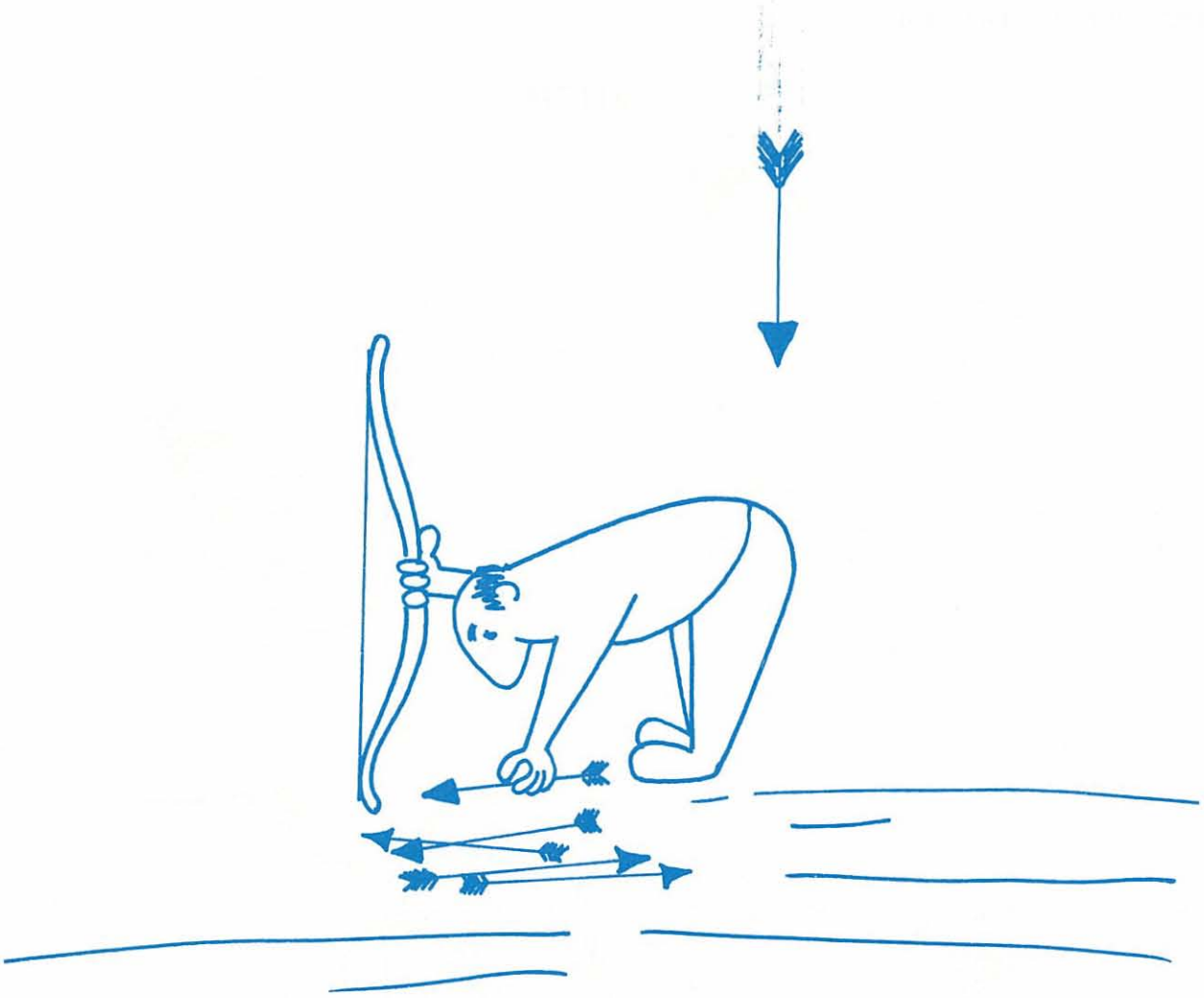


Figure 10A

GRAVITY

Gravity is one of the four outside forces that have an effect on all simple machines. Gravity is the force that draws all bodies toward the center of the earth. The force of gravity gives us weight, it causes objects to fall from the sky or roll down a hill. Figure 10A shows an example of gravity. The center of the earth has an attraction drawing everything to this center. If it is above the earth, gravity has a pulling effect drawing it to the surface. Objects readily move down hill because they are going toward the center of the earth. A weight dropped in a hole will go down because it is going toward the center of the earth.

INERTIA

Static inertia is the tendency of an object to remain at rest. Without some outside force the body tends to remain at rest and not move.

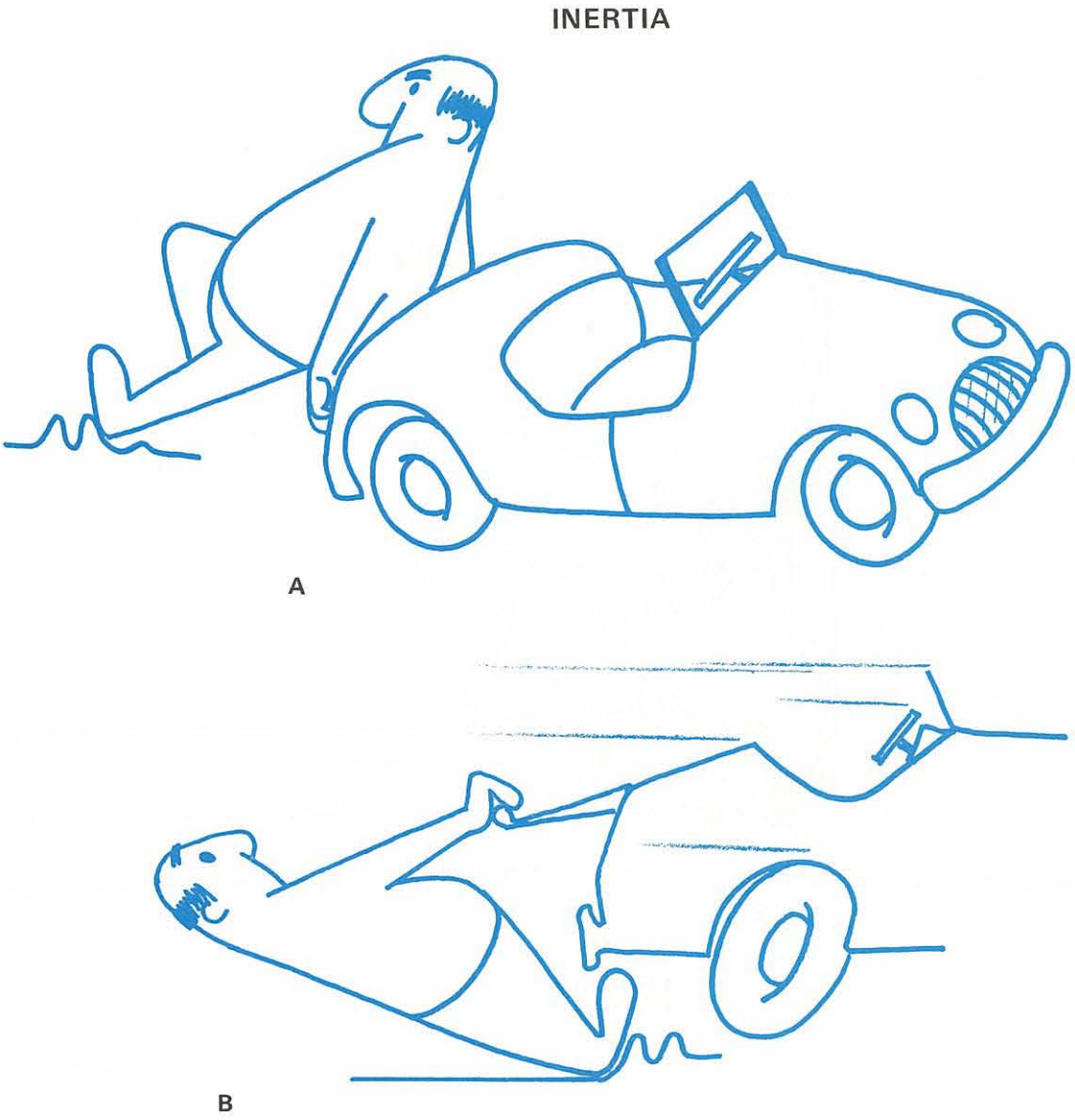


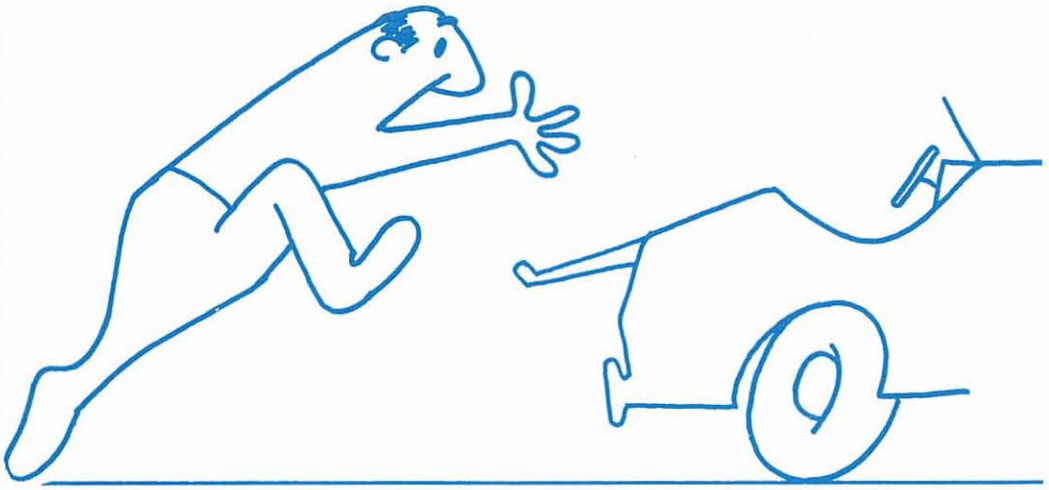
Figure 11A

Dynamic inertia is the tendency of an object to continue moving once it has been set in motion. Figure 11A shows an example of inertia. Static inertia is shown at A. The car is stationary on level ground. It does not want to move. Once the car is pushed and begins rolling the static inertia has been overcome and it becomes dynamic inertia. Once rolling, the car has a tendency to keep rolling or moving.

MOMENTUM

Momentum is the amount of motion of a moving object. See Figure 12A. Once you set an object, such as a car, in motion down a hill you can see the principle of momentum. As the car starts down the hill it moves very slowly, then it begins to pick up speed. The car is gaining momentum as it rolls down the hill.

MOMENTUM



MOMENTUM IS THE AMOUNT OF MOTION OF A MOVING OBJECT.

Figure 12A

RESISTANCE

Resistance is an opposing or retarding force. Figure 13A shows an example of resistance. Two forces pulling away or pushing against each other is resistance. Resistance is also present when two forces oppose each other, such as two rough surfaces running together. Resistance will often create friction. Various forms of resistance are often used in electrical components to retard the flow of electricity. Resistance is present in all engines caused by friction of the moving parts. Resistance is also present when an object is moving and has momentum. As a car gains momentum while rolling down a hill it has a resistance to being stopped.

RESISTANCE

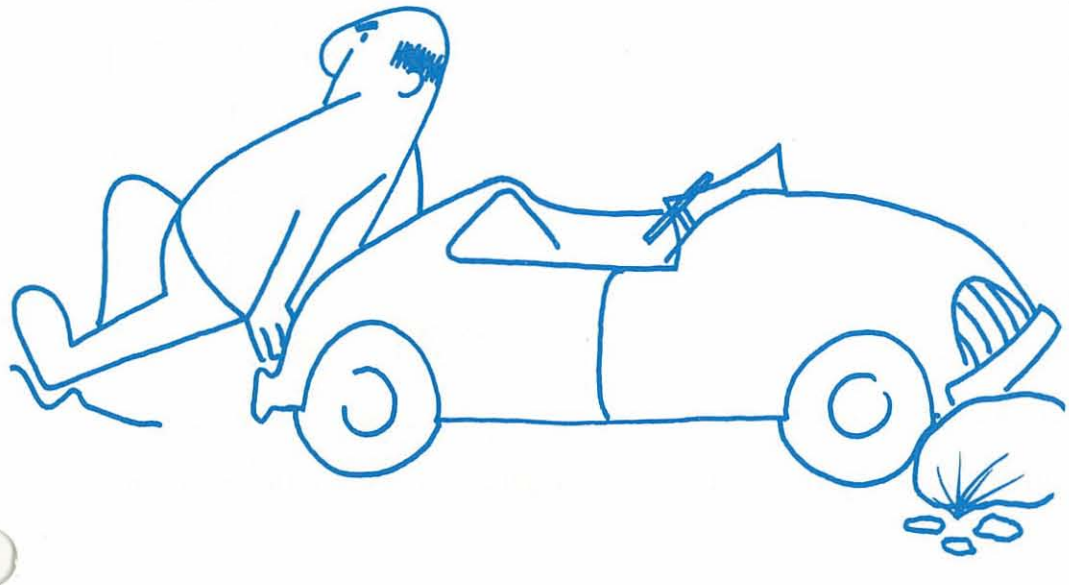


Figure 13A

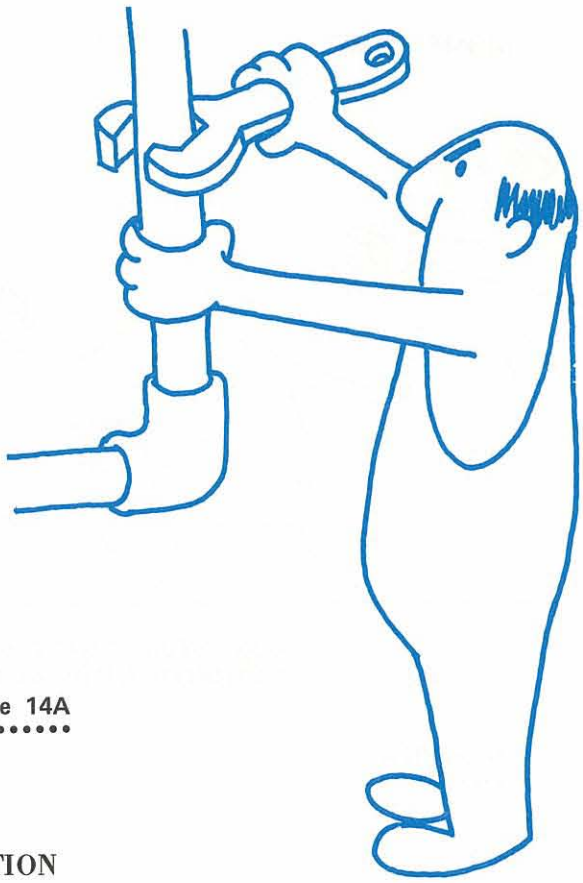


Figure 14A

TORQUE

Torque is a twisting or turning force. Figure 14A shows an example of torque. The twisting or turning force is related to the turning or rotation force of an object. The term "torque" is used often when referring to the tightness of a bolt or nut and the turning force developed on an engine crankshaft.

FRICTION

Friction is the resistance to motion of two or more surfaces in contact with each other. An example of friction is shown at Figure 15A. Friction is present in some degree anytime two or more objects are moved against each other. Two smooth surfaces will create less friction than two rough surfaces. A piston sliding up and down in the cylinder of an engine creates friction. If no oil were present the friction would be very great since oil reduces the amount of friction generated between two surfaces. Friction also causes heat to be generated which is the reason an engine must have some method of cooling.

FRICTION

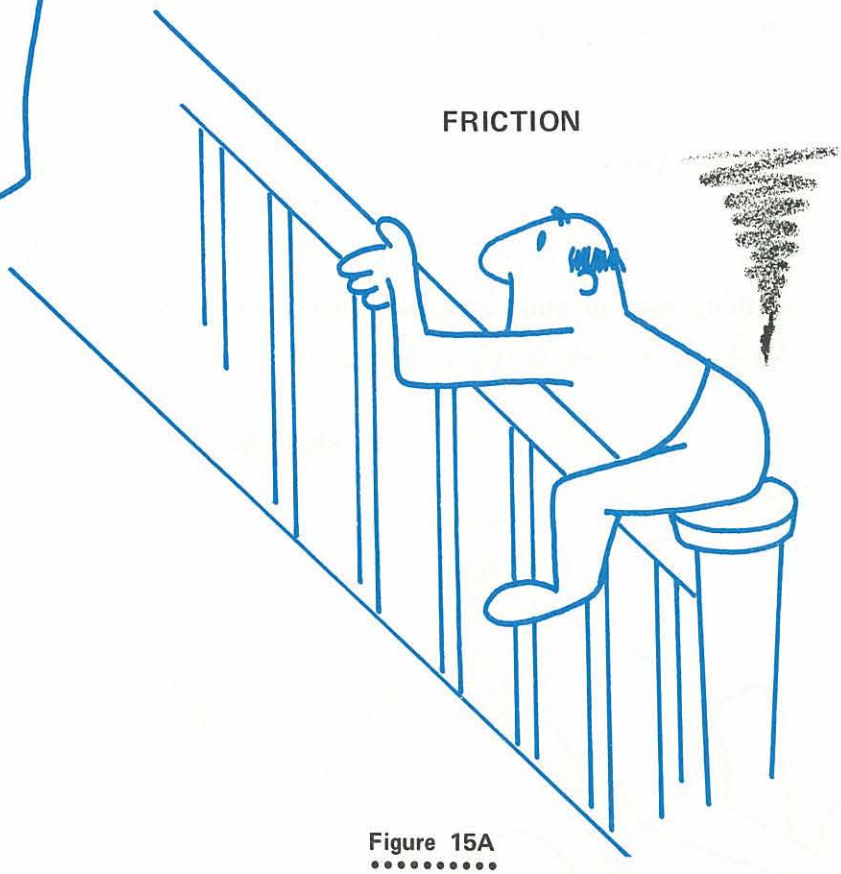


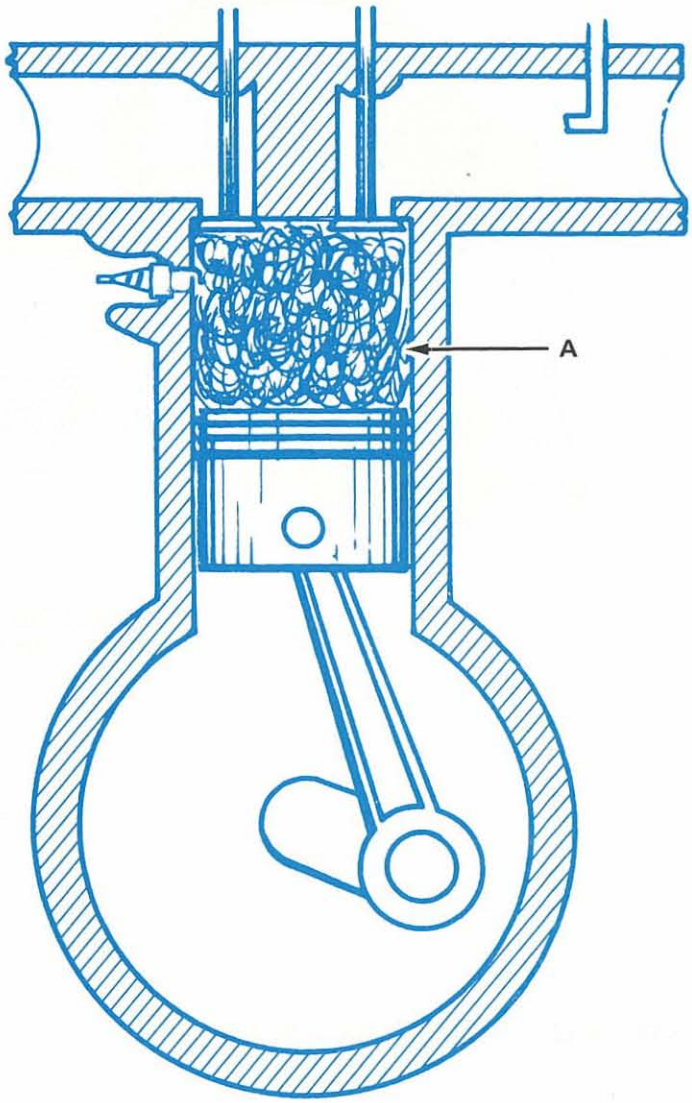
Figure 15A

INTERNAL COMBUSTION ENGINE

An engine is a machine that converts heat into mechanical energy. There are several methods in which heat energy can be used to convert it into mechanical energy. As they relate to engines they are generally considered to be internal or external combustion engines.

Figure 16A shows the basic principle of changing heat energy into mechanical energy with an internal combustion engine. To obtain combustion necessary to operate an engine fuel is mixed with air and ignited to produce heat. The heat is then changed into mechanical energy. Fuel and air are mixed inside the cylinder at A and ignited by a spark plug.

INTERNAL COMBUSTION ENGINE



FUEL IS BURNED INSIDE OF THE CYLINDER.

Figure 16A

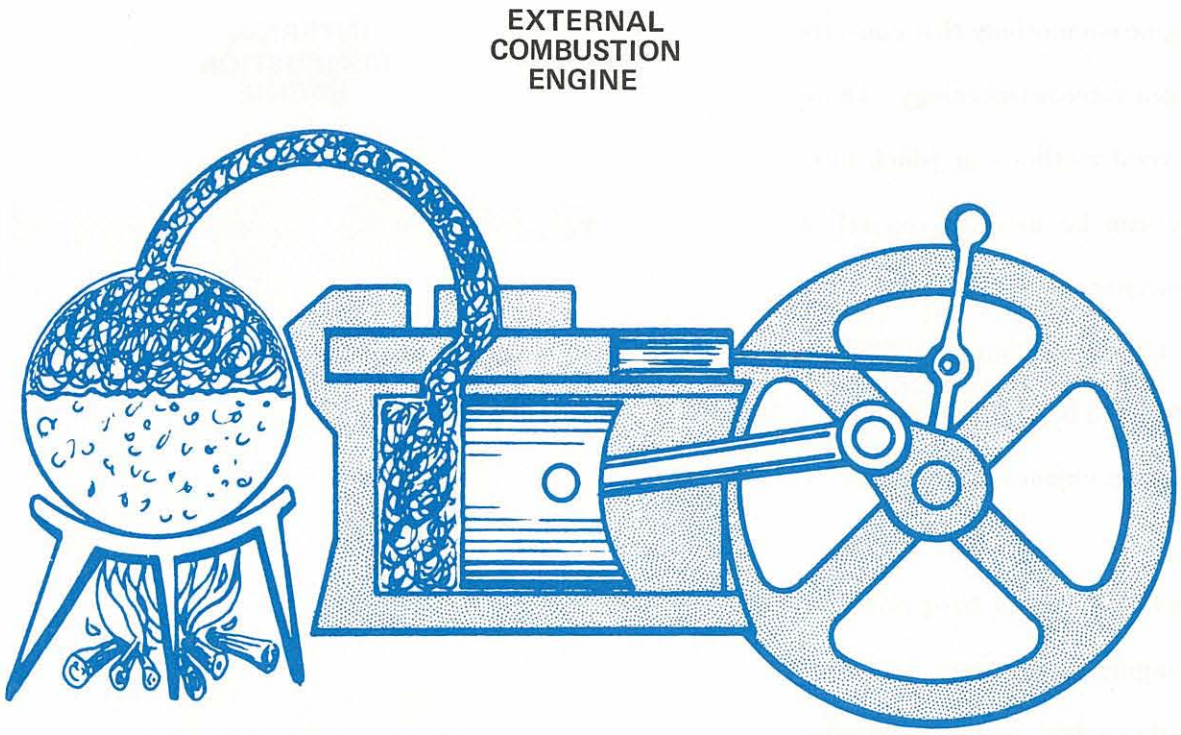


Figure 17A

EXTERNAL COMBUSTION ENGINE

Figure 17A shows the basic principle of the external combustion engine. Heat is changed to mechanical energy by changing water into steam. Steam then forces its way into the cylinder to operate the piston. Instead of a gas explosion forcing the piston back down as in an internal combustion engine, expanding steam forces the piston down. This is the basic principle of the steam engine, which is an external combustion engine.

COMPRESSION

Compression is a term that will be used in several ways in the description and function of an engine. The application of compression is shown in Figure 18A. The spring shown at A is being compressed in the direction of the arrows. As the pressure increases the spring is reduced in length in the direction of the compressing force. The action of engine valve springs is a typical example of this type spring compression. Another application of compression is shown at B. Liquids and gases are also compressed in an engine operation. As the pressure at B is increased on the rod it brings the liquid under pressure in the jar. This type of compression is applied to the fuel-air mixture in the cylinder of an engine. When gases are compressed they are reduced in volume. A spring can be reduced in length and a gas will reduce in volume when brought under pressure, however, liquids have practically a zero compression ratio.

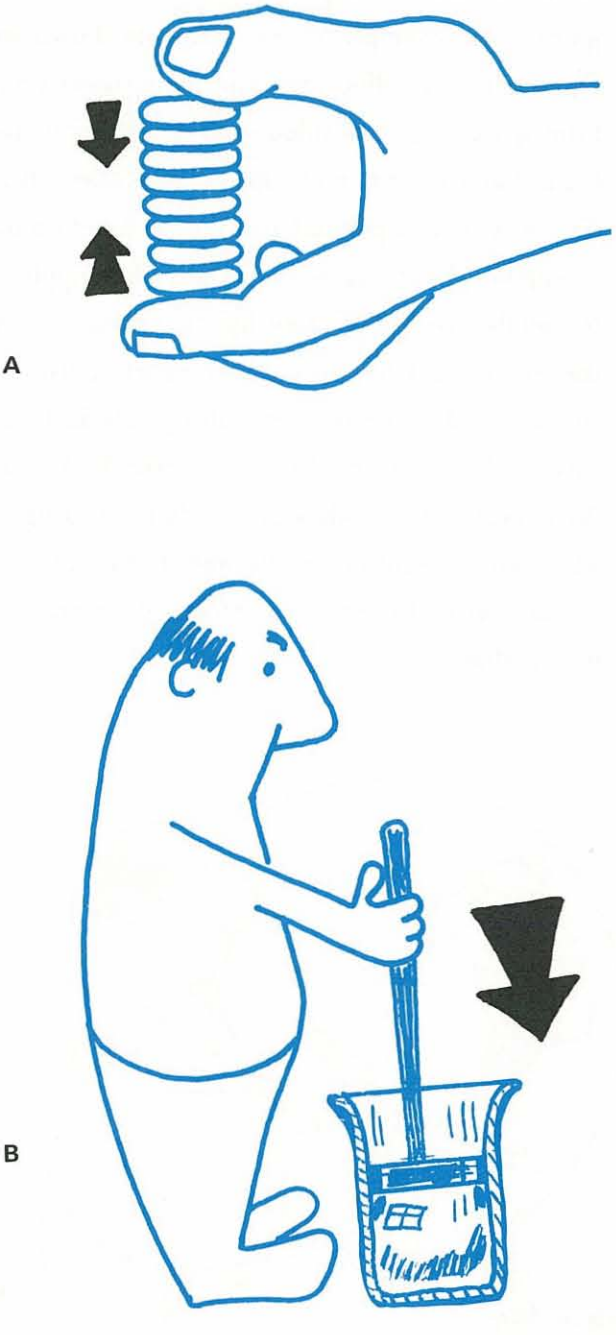


Figure 18A

EXPANSION

Expansion is the ability to spread out or fill more space. An example of expansion is shown in Figure 19A. A balloon without air occupies very little space. As it is filled with air, it begins to expand and occupy more space. This same principle is a very important part in the function of an engine. Heat causes expansion when applied to metals. Heat generated by the engine causes the operating parts to expand. Parts must be adjusted and fitted so they will operate in their expanded condition after the engine heats up. An engine fitted with a piston that is too tight when cold, would expand and freeze in the cylinder after the engines reaches its operating temperature.

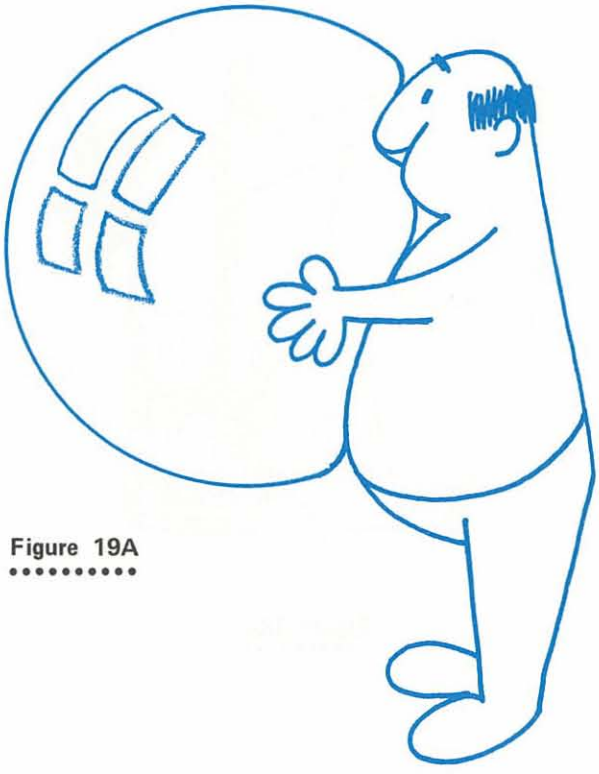


Figure 19A

CYCLE

A cycle is a complete series of events recurring in the same sequence. Figure 20A shows a typical example of a cycle. The seasons of the year constitute a cycle. Each season, Spring, Summer, Fall and Winter each follow in the same sequence. A 4-cycle internal combustion engine also has a series of four cycles. In order for this engine to complete one series of events it goes through the Intake, Compression, Power and Exhaust stroke. After the Exhaust stroke is complete, it repeats the cycle again and continues repeating until the engine stops.

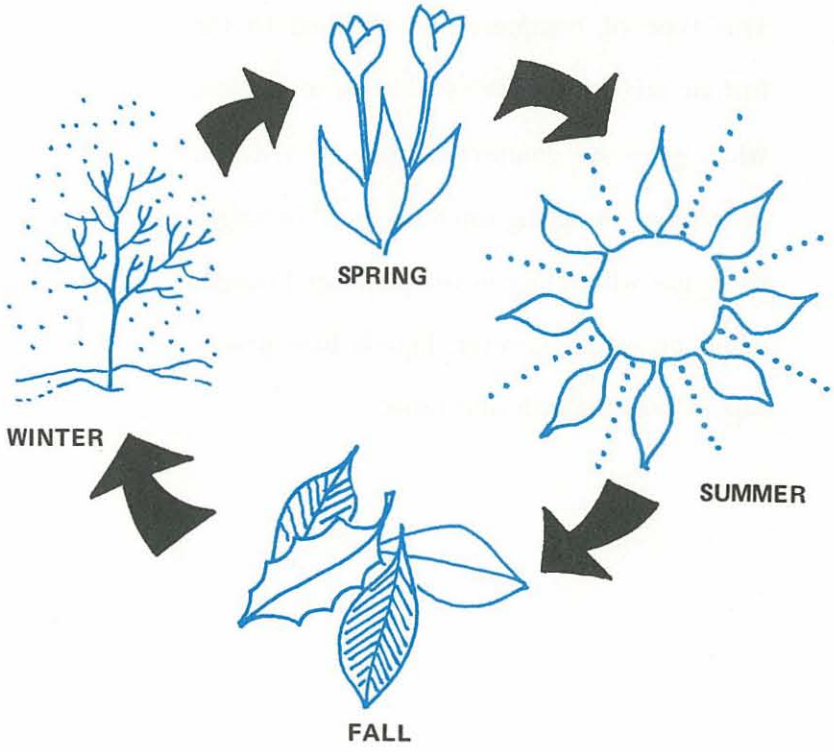


Figure 20A

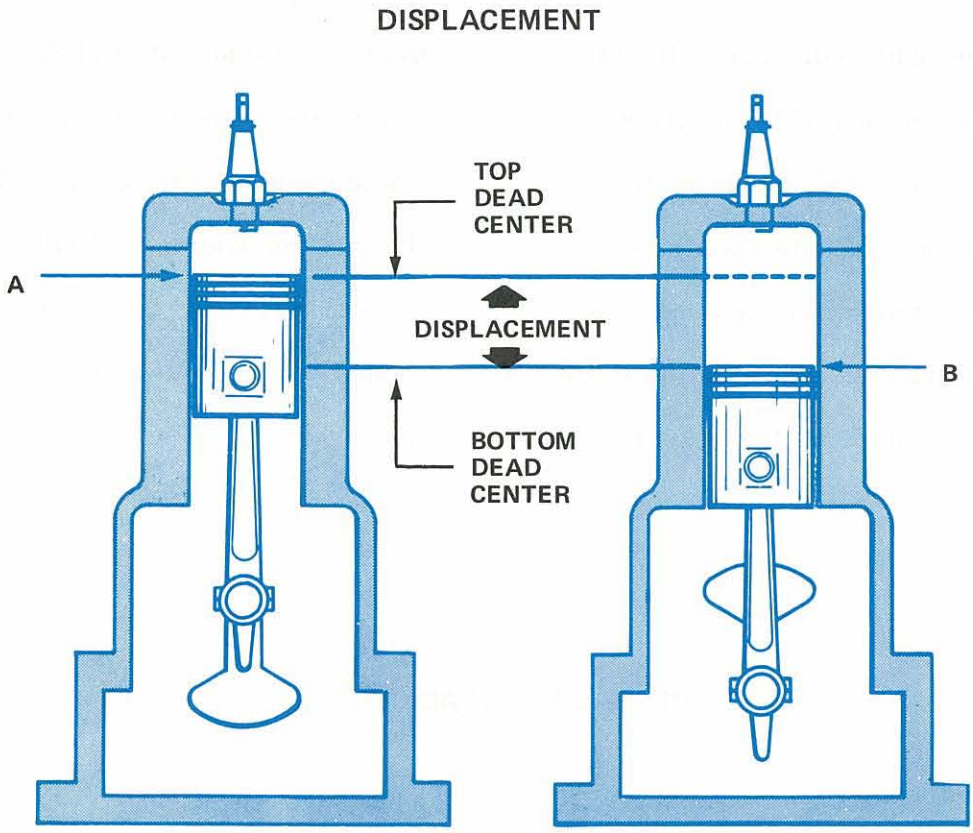


Figure 21A

DISPLACEMENT

Piston displacement is the difference between the top and the bottom of the stroke of the piston travel. Figure 21A shows the area in the cylinder known as Displacement. Study this drawing carefully as the three different factors that determine displacement will be used frequently later in the course.

Top Dead Center, known as TDC, is the furthest point of upward travel of the piston in the cylinder, as shown at A. Bottom Dead Center, known as BDC, is shown at B. This is the lowest point of downward travel of the piston in the cylinder. The space between TDC and BDC is known as Displacement. Piston Displacement is expressed in cubic inches.

TOP DEAD CENTER

The term, before and after Top Dead Center, will be used often later in the course. It is often abbreviated as BTDC and ATDC for After Top Dead Center. Figure 22A shows the location the piston should be in at these two positions. This shows the piston traveling in the up direction. When the piston reaches the point shown at A it is at BTDC. As the piston continues to travel up it reaches point B which is the maximum it will travel. This is known as TDC. After the piston reaches TDC, it begins to travel down. When it reaches point A on the down stroke, it is then in the position known as ATDC. The distance between BTDC and TDC will be covered later in the course as it relates to the timing of the engine.

BEFORE-TOP-DEAD-CENTER

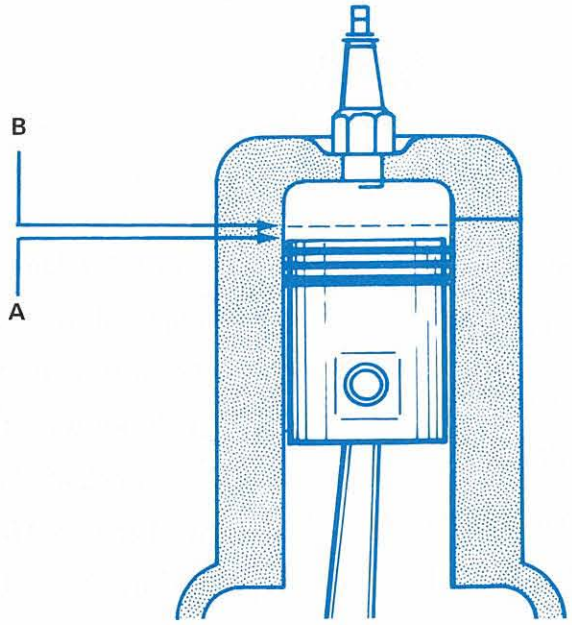


Figure 22A

BORE-STROKE

Piston stroke is the length the piston travels within the length of the cylinder. It is the distance between the maximum up stroke and the maximum down stroke as shown in Figure 23A. This maximum travel distance is shown at A. The Bore is shown at B. This is the diameter of the cylinder. The combination of the bore diameter and the length of the piston stroke determines the cubic inch displacement of the engine.

STROKE-BORE

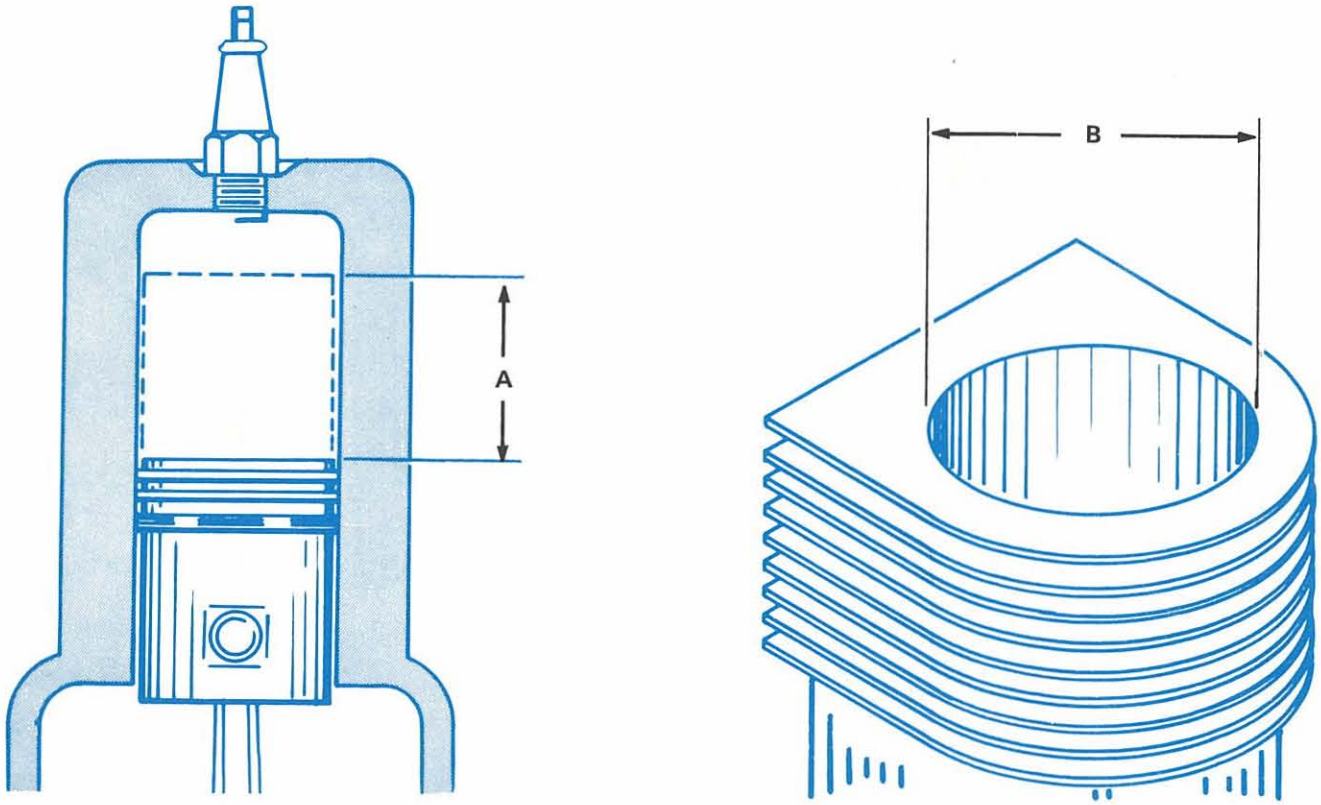


Figure 23A

PARTS OF THE PISTON

There are several parts of the piston that we will be referring to later in the course and we should be familiar with their names. Figure 24A shows a typical piston. The piston is the sliding part that rides up and down inside the engine cylinder. Most pistons have three rings, shown at A, that seal the gap between the cylinder wall and the piston. The piston also has Lands as shown at B. These are the metal ridges between the ring grooves. The piston skirt is the low hollow part of the piston shown at C. The skirt keeps the piston sliding straight up and down within the cylinder.

PARTS OF THE PISTON

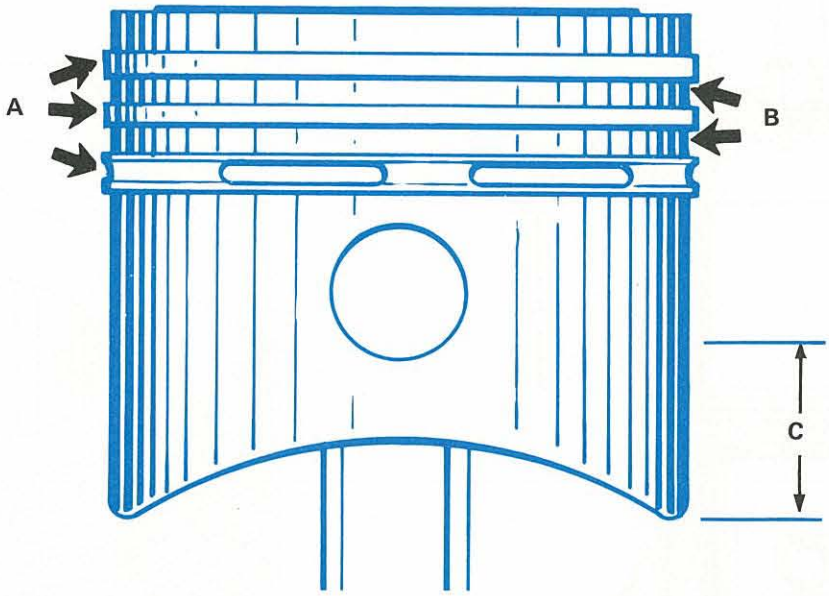


Figure 24A

SLEEVE

The sleeve is a hard, cylindrical insert installed inside the cylinder. The sleeve is inserted inside the cylinder with a very tight press fit and is made of a harder metal than the cylinder wall. Figure 25A shows a sleeve and cylinder. The use of a sleeve permits the cylinder to be made of different metals that otherwise would not be compatible with the hard metal of the rings. When sleeves are used the cylinder head is often made of a much softer metal.

SLEEVE

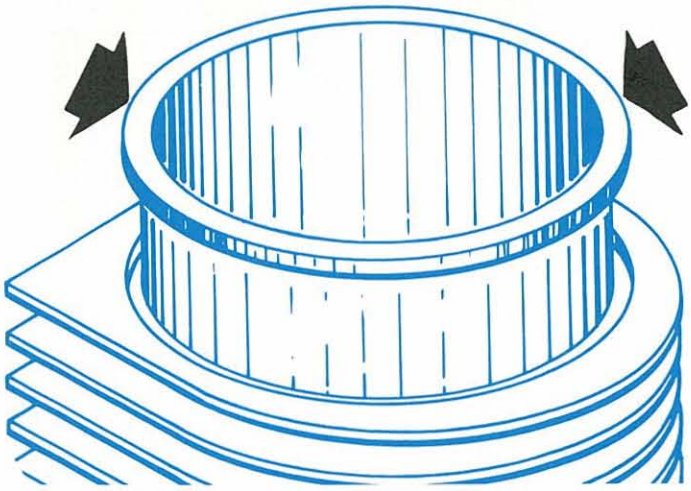


Figure 25A

PORT

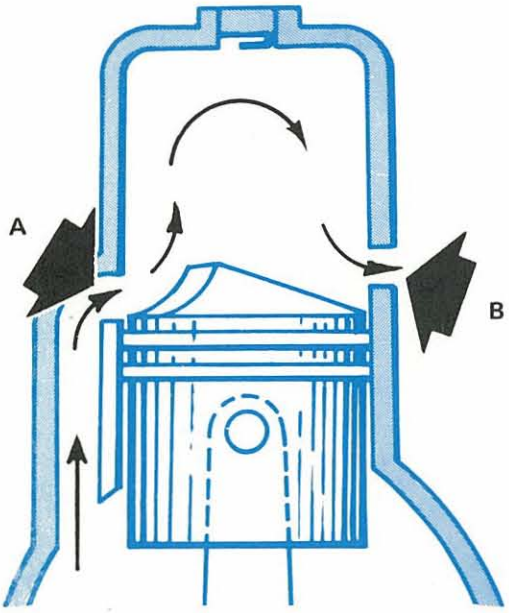
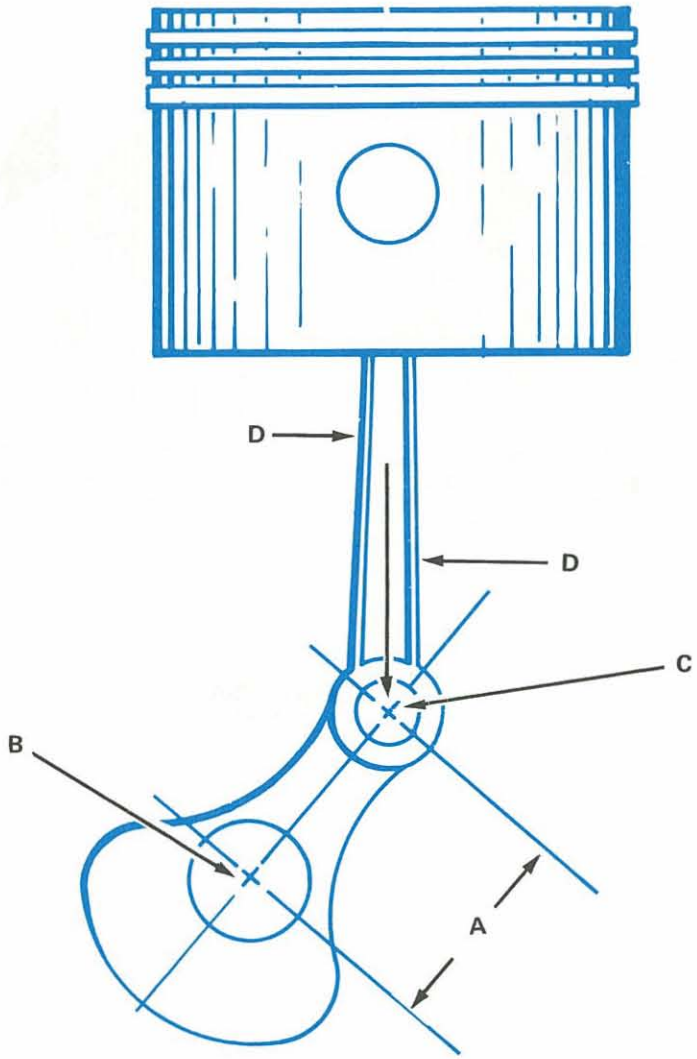


Figure 26A

PORT

A port is an opening in a part through which gases or liquids can flow. Figure 26A shows the ports used in a 2-cycle engine. Fuel and air mixture enters through the intake port shown at A. The port shown at B is the exhaust port through which the spent gases escape after combustion. When the piston is in the up position both of these ports are closed.



THROW AND THRUST

Figure 27A

THROW AND THRUST

Throw is the distance between the center of the crankshaft shown at A in Figure 27A and the center of the crankpin. The crankshaft is shown at B and the crankpin is shown at C. Thrust is a force directed along the axis of a part as shown at D. As the piston is forced down the thrust moves along through the connecting rod shown at D to the crankshaft at B. This thrust causes the crankshaft to turn.

COMPRESSION RATIO

There are three basic requirements necessary to make an engine operate. These things are air, fuel and ignition. All three of these must be present and in the proper proportion or an engine will not operate properly. By squeezing the fuel and air mixture up into one end of the cylinder more power can be obtained from the mixture. This is called Compression. The amount the fuel and air mixture is reduced in volume is called the compression ratio.

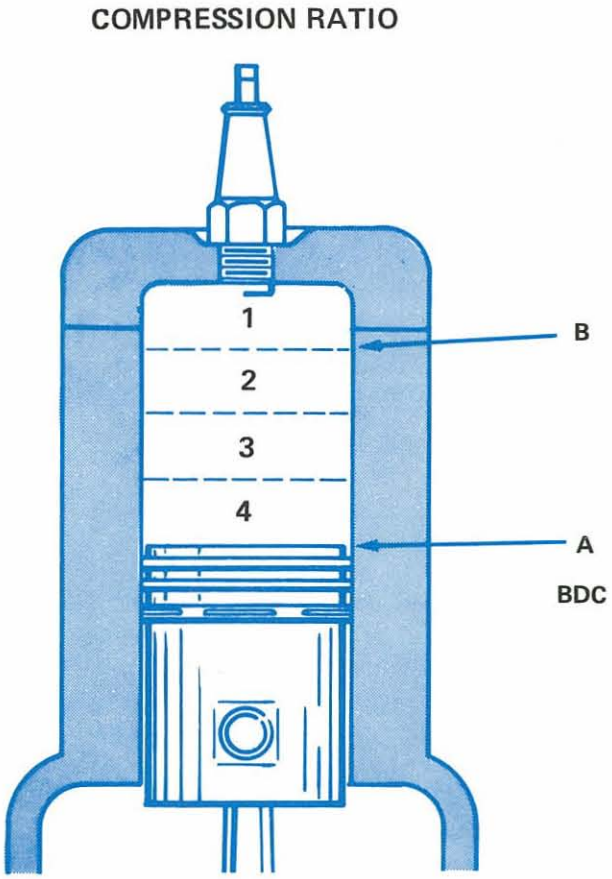


Figure 28A

Figure 28A shows an example of compression ratio. If the piston were at BDC, as shown at A, there would be 4 inches of space between the piston and the top of the cylinder. This space would be filled with a fuel-air mixture. As the piston moved to the top of the cylinder to point B, it would squeeze the mixture into one inch of space, creating a 4 to 1 compression ratio.

BLOW-BY

When the air-fuel mixture is ignited in an internal combustion engine, an explosion takes place that drives the piston back down into the cylinder to deliver power to the crankshaft. If the area in which this explosion takes place is not tight enough, power will be lost. Figure 29A shows how Blow-By effects an engine. The piston should have a tight fit between the rings and the cylinder wall shown at A and B. If this seal is not tight, much of the explosive force will be lost through this area.

BLOW-BY

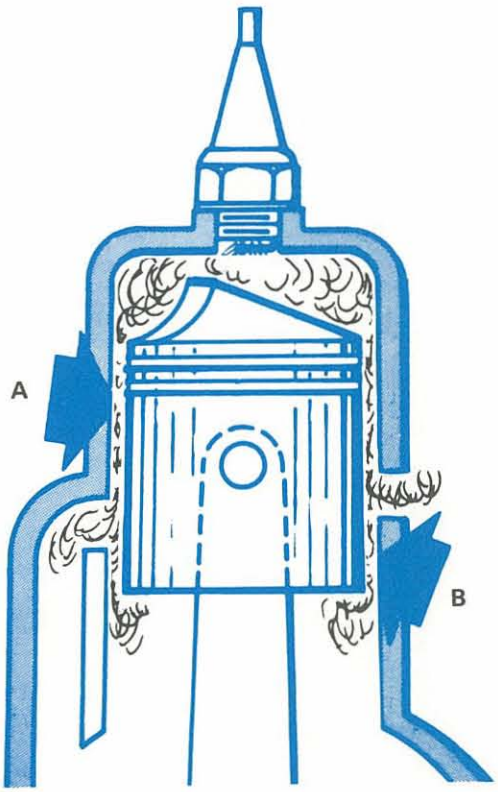


Figure 29A

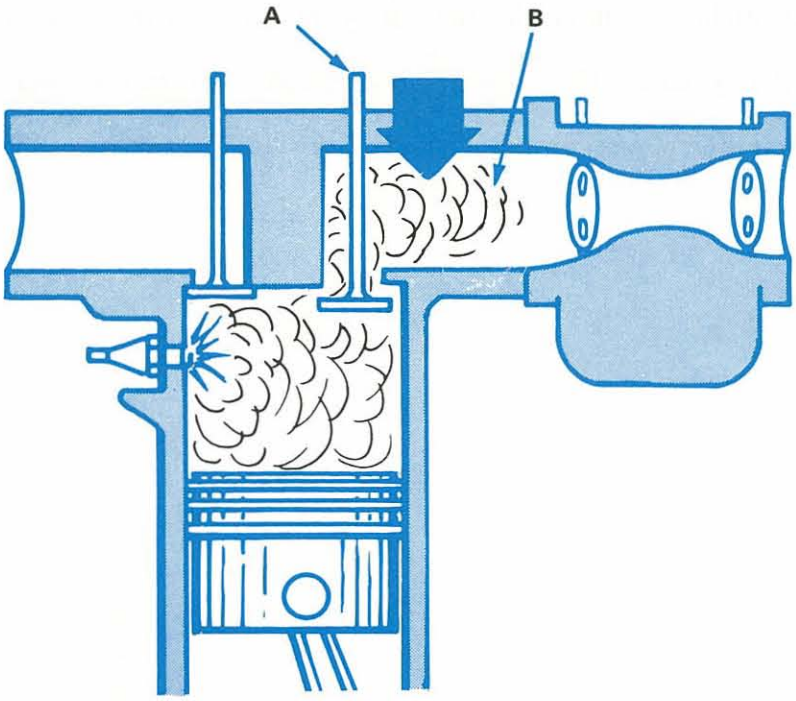


Figure 30A

BACKFIRE

Backfire occurs when the fuel-air mixture ignites before it is supposed to. This is usually due to improper timing as shown in Figure 30A. If the valve shown at A does not close at the proper time, the fuel-air mixture may ignite in the intake manifold as shown at B. Backfire can also occur in the exhaust system due to incorrect timing or poor combustion. Regardless of its source, backfire is a sign of poor engine operation.

RECIPROCATING AND ROTARY MOTION

An engine first produces reciprocating motion by the action of the explosive forces driving the piston up and down in the cylinder. This action is then turned into rotary motion. Figure 31A shows these two motions. As the piston moves down, it applies a thrust to the crankshaft which turns it in a circular motion.

RECIPROCATING AND
ROTARY MOTION

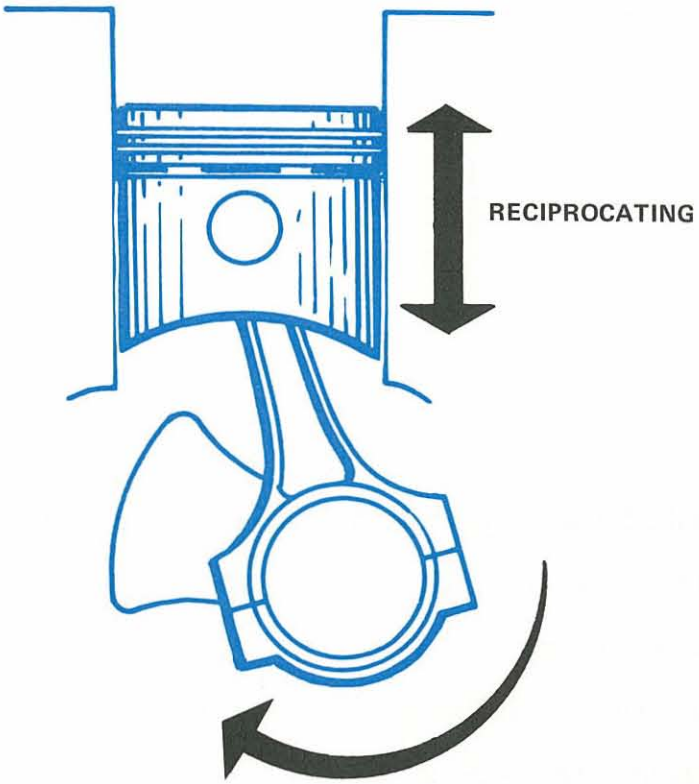
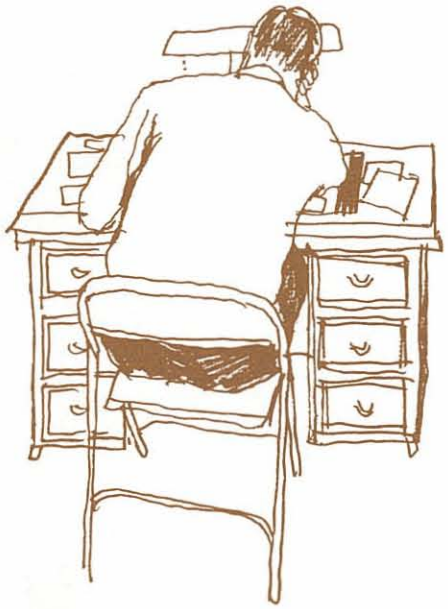


Figure 31A



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Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

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- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

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3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. _____ is the amount of motion of a moving object. _____
   a. torque
   b. resistance
   c. momentum

2. _____ is the tendency of a body to continue moving after it has been set in motion. _____
   a. resistance
   b. friction
   c. dymanic inertia

3. _____ is a twisting or turning force. _____
   a. momentum
   b. torque
   c. resistance

4. _____ is the ability to do work. _____
   a. resistance
   b. inertia
   c. energy

5. Resistance will create _____. _____
   a. friction
   b. gravity
   c. momentum

6. The strokes of a four cycle engine are intake, compression, power and exhaust. _____
   TRUE
   FALSE

7. _____ is the distance the piston travels within the cylinder. _____
   a. bore
   b. sleeve
   c. piston stroke

8. A loose fit between the rings and the cylinder wall will cause _____. _____
   a. compression
   b. expansion
   c. blow-by

(Continued on page 2)

9. Internal combustion engines convert heat into _____ energy. _ ___
   a. fuel
   b. mechanical
   c. inertia

10. The basic principles of mechanical advantage are the lever, incline plane, screw, pulley, and the wheel and axle. _____
    TRUE
    FALSE

11. The _____ is a simple method of increasing the amount of force that can be exerted on a object. _____
    a. lever
    b. incline plane
    c. screw

12. Location of the _____ determines the amount of force necessary to be applied to the long end of a lever. _____
    a. screw
    b. incline plane
    c. fulcrum

13. _____ is the force that draws all bodies toward the center of the earth. _ ___
    a. gravity
    b. force
    c. kinetic

14. The wheel and axle transmits weight or load into rotary motion. _____
    TRUE
    FALSE

15. _____ is a push or pull on an object in an attempt to change its condition. _____
    a. fulcrum
    b. gravity
    c. force

16. _____ is a opposing or retarding force. _____
    a. fulcrum
    b. gravity
    c. resistance

17. TDC is known as top-dead-center. _ ___
    TRUE
    FALSE

18. A _____ is a hard cylindrical insert inside the cylinder. _____
    a. piston
    b. sleeve
    c. port

19. When gasses are compressed, they are reduced in volume. _ ___
    TRUE
    FALSE

20. BDC is known as bottom-dead-center. _____
    TRUE
    FALSE

(Continued on page 3)

21. _____ is the movement of a object or weight through a distance. _____
    a. inertia
    b. work
    c. momentum

22. The parts of the piston are rings, lands and skirt. _____
    TRUE
    FALSE

23. BTDC is known as before-top-dead-center. _____
    TRUE
    FALSE

24. _____ is the amount the fuel and air mixture is reduced in volume when under pressure. _____
    a. throw and thrust
    b. compression ratio
    c. bore and stroke

25. The bore and stroke are the two basic parts of the lever principle. _____
    TRUE
    FALSE

26. When an object begins to move potenial energy is changed to kinetic energy. _____
    TRUE
    FALSE

27. ATDC is known as at-top-dead-center. _____
    TRUE
    FALSE

28. A _____ is a opening in a part through which gasses or liquids can flow. _____
    a. stroke
    b. bore
    c. port

29. The diameter of an engine cylinder is called the _____. _____
    a. stroke
    b. bore
    c. piston

30. The _____ principle can be demonstrated by rolling a wheel up a hill. _____
    a. gravity
    b. momentum
    c. incline plane

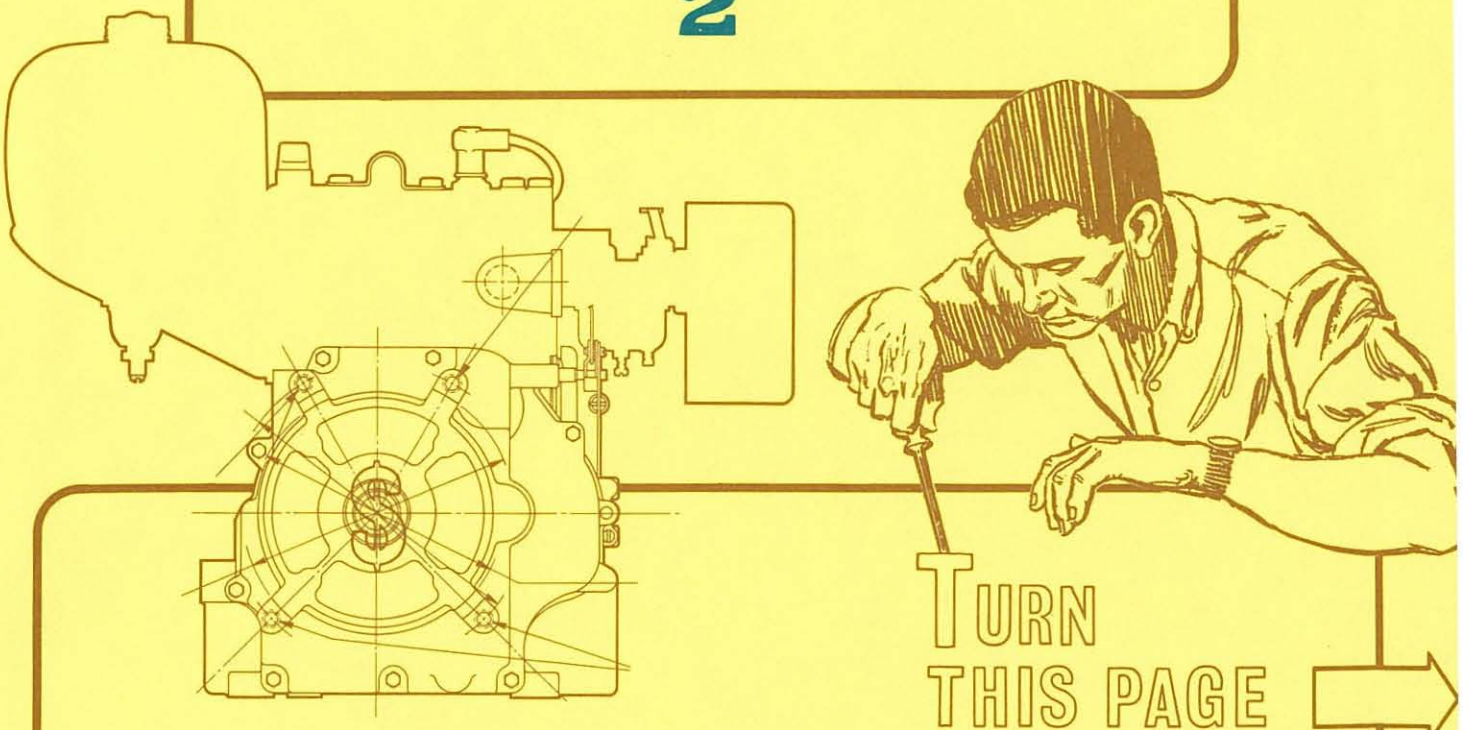
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

2



TURN THIS PAGE

...and let's find out all about --

PRINCIPLES AND TERMS
RELATING TO SMALL ENGINES

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ENGINE PRINCIPLES

Small engines used to power lawn mowers, garden tractors, chain saws, roto tillers and many other pieces of equipment are basically similar. They require the same basic intake of fuel and air to produce their desired result. They are known as Internal Combustion Reciprocating Engines. First we have to have something to make them operate. A source of energy is necessary that can be converted to power. Power is then converted to some form of motion.

Before we get further into the operating principle of these engines, we'll review some of the terms used to describe the different results an engine is designed to produce.

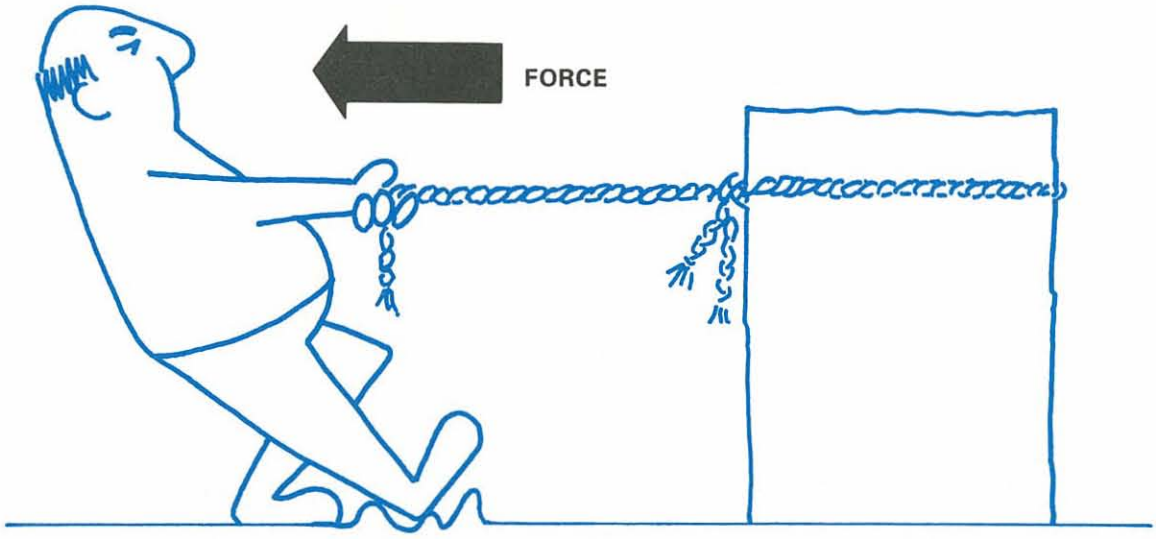


Figure 1

FORCE

Force is any action that is applied against an object that will cause it to move or have a tendency to move. Force has a tendency to accelerate an object from a state of rest to a state of motion or movement. Force is pressure against an object and is used in calculating torque or horsepower which we will cover later. These terms used to describe the different results produced by an engine have a value. As these values are related to one another they produce formulas that can give us a definite answer. Force is measured in pounds.

Figure 1 is an example of force. There is an action tending to move an object but the object is not moving. Force is applied but since the object does not move, there is no work accomplished.

WORK

When a force is applied to move an object from a state of rest or accelerates the movement of an object from one place to another, work is done. Work also has a unit of measurement. Work is measured by multiplying the force by the distance the object is moved. So, we have the formula:

WORK = FORCE x DISTANCE

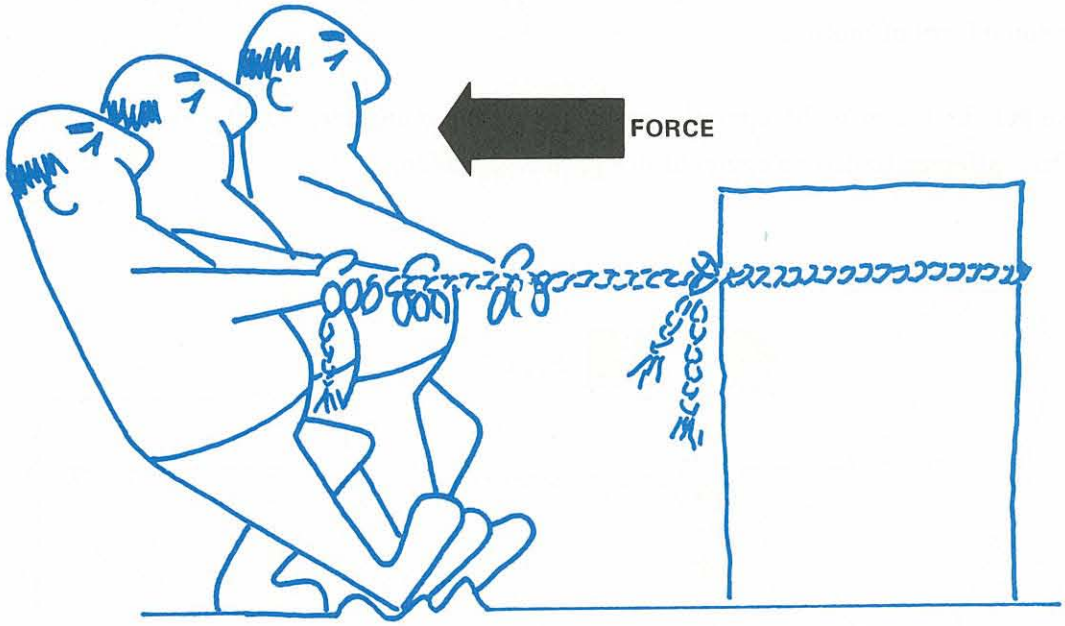


Figure 2

Figure 2 shows an example of Work. Force is applied to the object and the object moves from a state of rest. It moves from one place to another. If we had a force of 50 pounds and moved the object 50 feet we would have accomplished Work. If we apply the formula, Work = Force x Distance, we would have 2500 foot-pounds of work accomplished.

POWER

Power is the rate of time that it takes to accomplish the work performed. We use the same formula of force times distance but we divide by the time element it takes to perform the work. So, for Power we have the formula:

$$\text{power} = \frac{\text{force x distance}}{\text{time}}$$

Example: $\frac{50 \times 50 = 2500}{20} = 125 = \text{Power}$

From this formula we can see that power must increase if the time in which the work is done decreases.

Example: $\frac{50 \times 50 = 2500}{10} = 250 = \text{Power}$

HORSEPOWER

Horsepower is a unit of measurement of power. One horsepower has been designated as being able to do 33,000 foot-pounds of work in one minute. This evaluation has been universally accepted as the formula for determining horsepower for many years.

Figure 3 shows an example of horsepower. In order to determine horsepower we can multiply the number of pounds being moved by the number of feet it is moved and then divide this figure by the product of 33,000 pounds times the number of minutes.

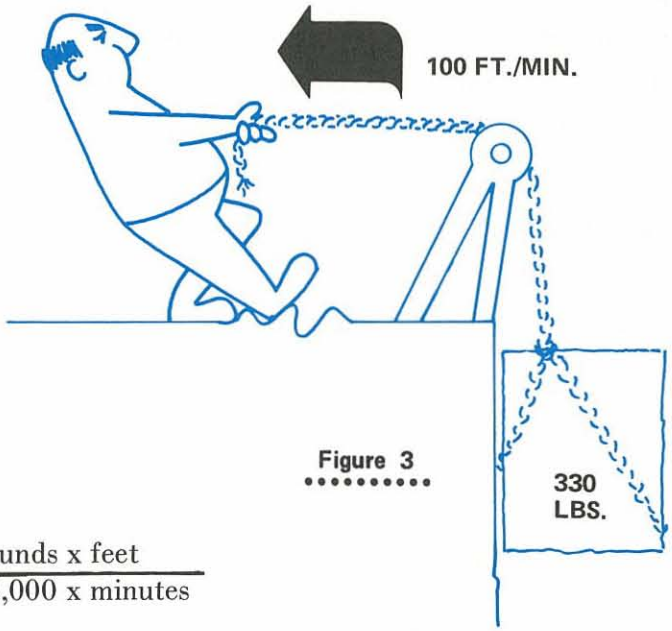


Figure 3

From this we have the formula, horsepower $= \frac{\text{pounds x feet}}{\text{33,000 x minutes}}$

Example: $\frac{\text{330 pounds x 100 feet} = 33{,}000}{\text{33,000 x 1} \quad = 33{,}000} = 1$ horsepower.

Another example of horsepower is to move 5000 pounds 30 feet in two minutes.

Example: $\frac{\text{5000 pounds x 30 feet} = 150{,}000}{\text{33,000 x 2 minutes} \quad = 66{,}000} = 2.27$ horsepower.

BRAKE HORSEPOWER

When referring to engine horsepower it is generally referred to as brake horsepower or rated horsepower. Brake horsepower is the maximum horsepower from an engine as determined by a dynamometer. A dynamometer is an instrument used for testing engines. We'll cover some of their functions just a little later.

This horsepower rating is usually stated as maximum observed horsepower or corrected brake horsepower. Observed brake horsepower will vary under certain conditions such as temperature and atmospheric pressure. Corrected brake horsepower is the horsepower calculated from observed brake horsepower and is a means of comparing engines tested under varying conditions, such as temperature and atmospheric conditions.

RATED HORSEPOWER

Rated horsepower is used as a safety factor to keep from overloading an engine. If a gas engine is operated at it's very maximum capacity at all times, we know it will have a very short life. Even though our automobile may be rated at 120 miles per hour it will seldom last very long if driven at this top speed. Occasionally we can go up to this speed for short periods but sustained driving will destroy the engine.

An engine being operated at it's maximum rating (brake horsepower) will not have reserve power for overloads and would be subject to damage from overheating and rapid wear.

An engine is selected for a particular job or load. The engine brake horsepower rating should be in excess of the expected normal operating load. Generally, it is recommended that an engine not be operated in excess of 80% of the maximum brake horsepower. This gives a 20% margin for overload.

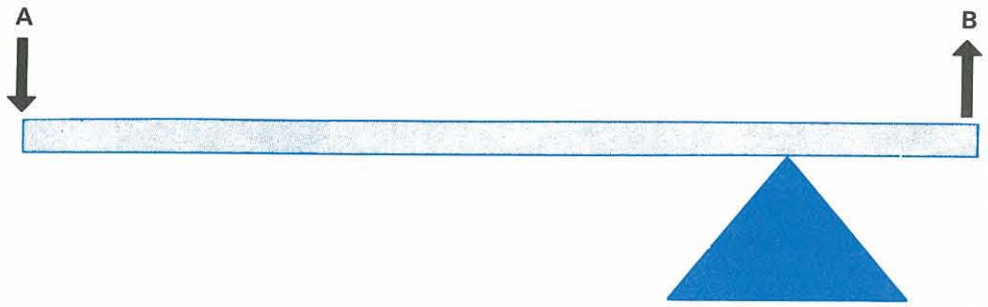


Figure 4

TORQUE

The "torque rating" of an engine is defined as the turning effort exerted by the output shaft when under load.

Torque can be expressed in a little different way that is easier to understand. It is similar to the law of the fulcrum. We know that by using a long-handled nail puller it is easier to pull a nail than with a short-handled hammer. This is basically the law of the fulcrum.

Figure 4 illustrates this principle. If pressure were exerted at point A in the direction of the arrow there would be a large amount of force exerted at point B in the direction of the arrow. This would be the same as high torque.

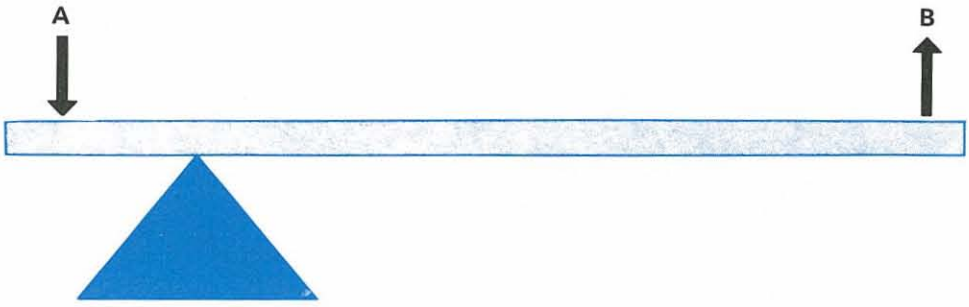


Figure 5

See Figure 5, if pressure were exerted at point A there would be very little pressure or torque exerted at point B in the direction of the arrow. Using this law of the fulcrum, it is possible to calculate the amount of force necessary at point A to lift a given weight at point B. The position of the fulcrum in relationship to the length between A and B determines this formula. It is also possible to calculate the engine horsepower actually being developed by measuring torque being developed and the engine output speed.

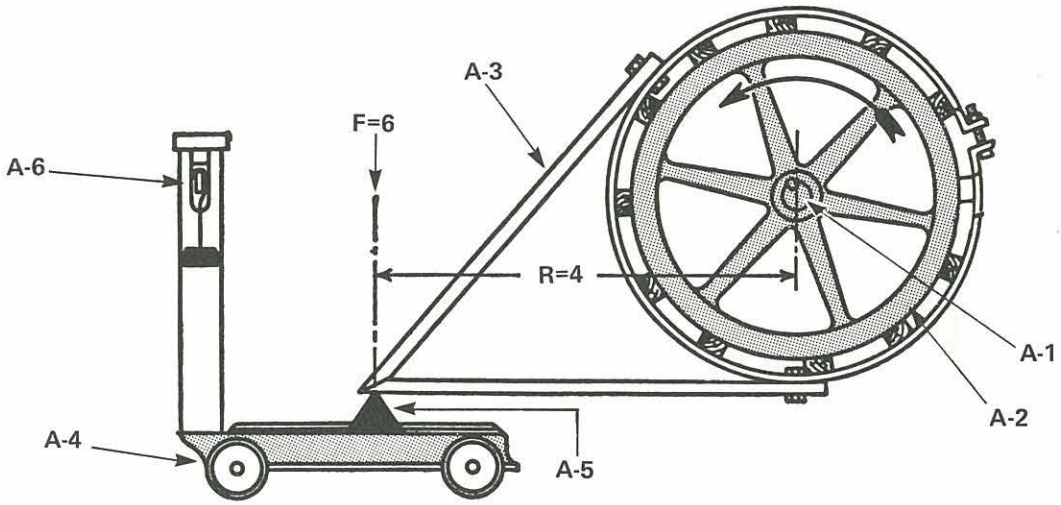


Figure 6

MEASURING TORQUE AND HORSEPOWER

A procedure known as a Prony Brake is used to test engine performance. Figure 6 shows the principles involved in a Prony Brake and how the calculations are made. Point A-1 is the motor shaft with a pulley A-2, mounted on the motor shaft. A torque arm as shown at A-3 is temporarily attached to the pulley mounted on the motor shaft. When the pulley turns or exerts pressure the torque arm must move. A-4 is a set of scales for measuring weight. When the torque arm, A-3, exerts pressure on the scale at A-5 it will cause a reading on the scales at point A-6.

Note the letter "F", this indicates the force on the scale. The letter "R" is the length of the torque arm radius. A-6 is the reading of the pounds pressure or weight the scale is recording.

From this arrangement we develop the engine torque formula. An engine can be set up to be tested under these conditions to actually measure engine torque. This is known as the Prony Brake method.

DYNAMOMETERS

Some dynamometers are available in small shops but they are very rare. The cost is almost prohibitive. They have a hydraulic loading device and scales to indicate engine speed and load. Horsepower is then calculated by instruments. We just mentioned the terminology of dynamometers so you will be familiar with the name. In the operation of the average large or small shop you will not run across its application.

ENGINE HORSEPOWER VARIATIONS

Engine efficiency will vary with the amount of air taken into the cylinder on each intake stroke. Because of this, the air density will have an effect on the horsepower output. Air density varies with both temperature and atmospheric pressure. Changes in air temperature, barometric pressure or elevation will cause a change in engine horsepower. Horsepower will decrease with elevation, drop in barometric pressure and rise in temperature. If you have ever driven in high mountains you probably have noticed the decreased performance of your car engine. On extremely hot days, a car's performance is not as good as it is on cooler, damp days.

There are two basic designs used in most all small engines. The most common is called the 4-Cycle. This engine requires a separate system for lubrication. This design is similar to some automotive engines in that it has a separate crankcase for oil to lubricate the engine. The 2-Cycle engine is lubricated by pre-mixing oil with the fuel. It has no separate oil supply like the 4-Cycle engine.

Figure 7 shows a cross section view of a typical 4-Cycle engine. This system has an oil supply that has to be kept almost full and operated on a fairly level surface in order to lubricate the internal moving parts. The oil level is shown at A-1. Oil is sent to the moving parts by means of an oil pump or slinger system. When using the slinger system there is a small cup or blade attached to the rod assembly shown at A-2. This will throw oil up on the moving parts. Note the position of the oil level at A-3. It would receive inadequate lubrication if operated for any length of time in this position.

LUBRICATION SYSTEM
(4 CYCLE ENGINES)

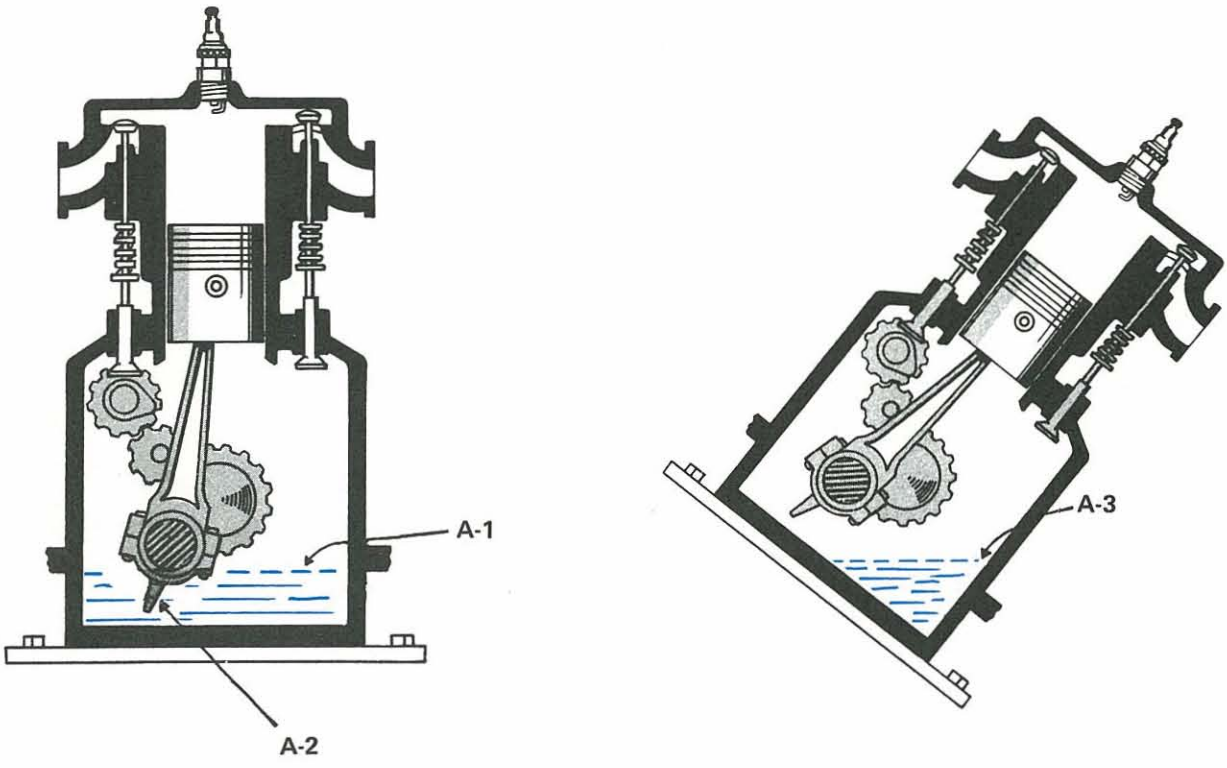


Figure 7

LUBRICATION SYSTEM
(2 CYCLE ENGINES)

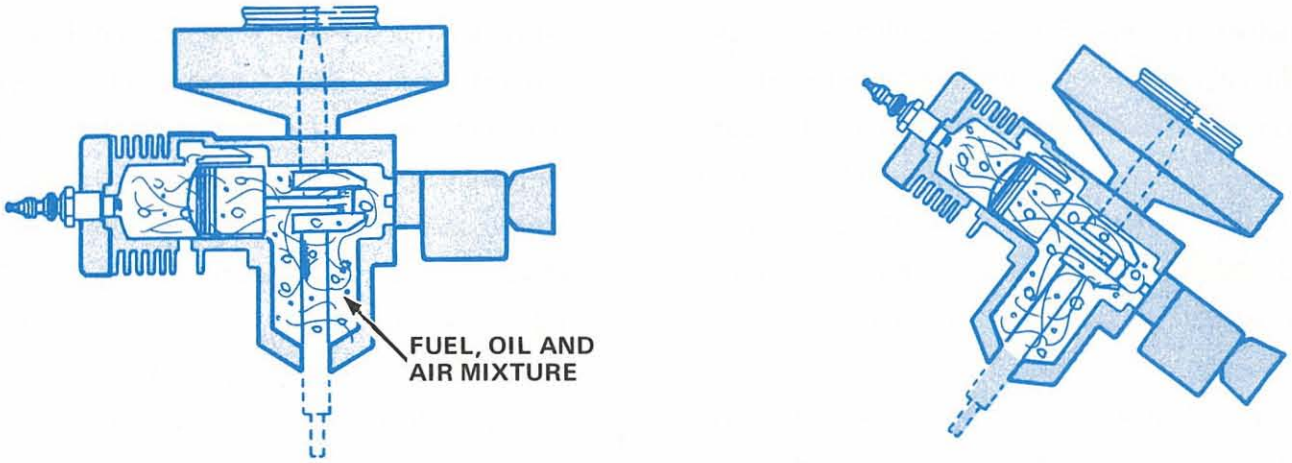


Figure 8

Figure 8 shows a cross section of a typical 2-Cycle engine. This system is always lubricated as long as the proper fuel is used. No attention to the oil level is required as the oil is pre-mixed with the fuel. This engine is kept properly lubricated regardless of the angle of operation while the 4-Cycle engine can only be operated in an upright position.

The oil is suspended in the fuel vapor and adheres to the surface of all moving parts, keeping them continually coated with a film of oil.

Even though both of these engines produce basically the same results, certain applications make one or the other more adaptable to an individual operation.

Each have their desirable and undesirable features. Generally speaking, the 4-Cycle engines are easier to start as raw fuel will ignite more easily than fuel mixed with oil. 2-Cycle engines are easier to maintain because there are fewer moving parts to wear and lubrication reaches every moving part on every stroke of the piston. Oil is always fresh and clean. Clean lubrication means longer life for any engine.

ENGINE APPLICATIONS

The purpose of this course is to help you gain a practical working knowledge of small engines so you can service and repair them. Engines of different horsepower, manufacturer, and application will vary slightly in appearance. They all basically operate on the principle of the internal combustion engine. In addition to the complete coverage of all functions of the engine itself, you will learn why certain accessories, such as the carburetor, air cleaners, crankcase breathers, storage batteries and other accessories require frequent servicing and why neglect can cause problems with the engine.

It is estimated there are more than 70 million small engines now in use in this country. They all need servicing at some time or another. Indications are there will be thousands more added each year because of new applications. Just a few years ago there were few power lawnmowers owned by the average family. Today it is a rare family living in a house that does not have, at least, one small engine used to power their lawnmower, snow blower or other application.

Here are just a few of the machines or equipment powered by small engines:

Post-hole diggers	Sump pumps	Irrigation pumps
Go carts	Chain saws	Mini-bikes
Small tractors	Conveyors	Motorcycles
Snow blowers	Rotary tillers	Bush cutters
Lawnmowers	Outboard motors	Power bicycles
Lawn edgers	Ice augers	Sprayers
Air compressors	Elevators	Generators
Small feed grinders	Earth drills	Golf carts
Concrete vibrators		

Mass production has made it possible for manufacturers to provide these small engines at prices almost anyone can afford. They are easily adapted to many small jobs and applications. They are compact and light weight, air-cooled, self-contained and easy to service and repair by someone with the proper training.

DISTINGUISHING FEATURES OF THE SMALL ENGINES

In order to meet the requirements of the many different applications, these engines are made with different features and designs. The engine itself is basically the same. Most of the variations are in accessories, such as different types of starters, carburetors and ignition systems. Some have the cylinder block made of aluminum, magnesium alloys or from cast iron. These metals are used to make the weight of the engine more compatible with the particular job it is designed to do. One major difference is the number of strokes or cycles which we will cover in detail later in the course. One distinguishing feature of these engines is the position in which it is to be used. There are three basic operating positions for most small engines.

VERTICAL CRANKSHAFT ENGINES

The vertical crankshaft engine as shown in Figure 9 has a cylinder that operates in a horizontal position. The vertical crankshaft engine is well adapted to mounting a mower blade or other equipment requiring horizontal movement. Before the vertical crankshaft engine became popular it was necessary to have some type of right angle drive to accomplish the same action of the vertical shaft design engine.

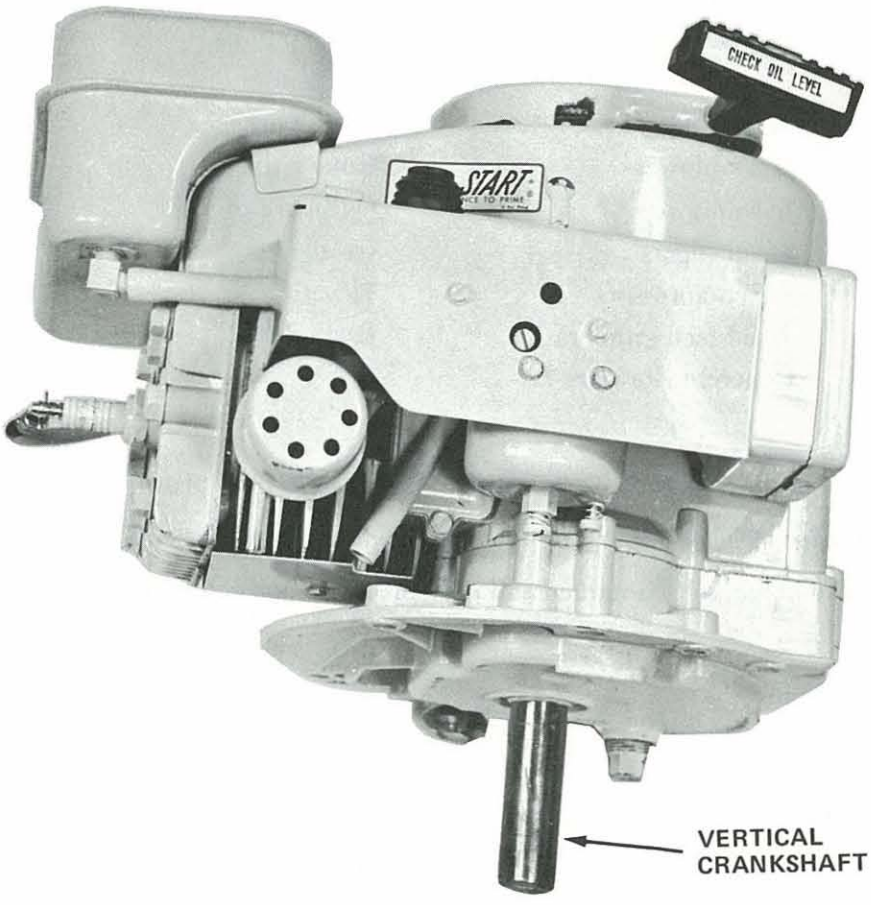


Figure 9

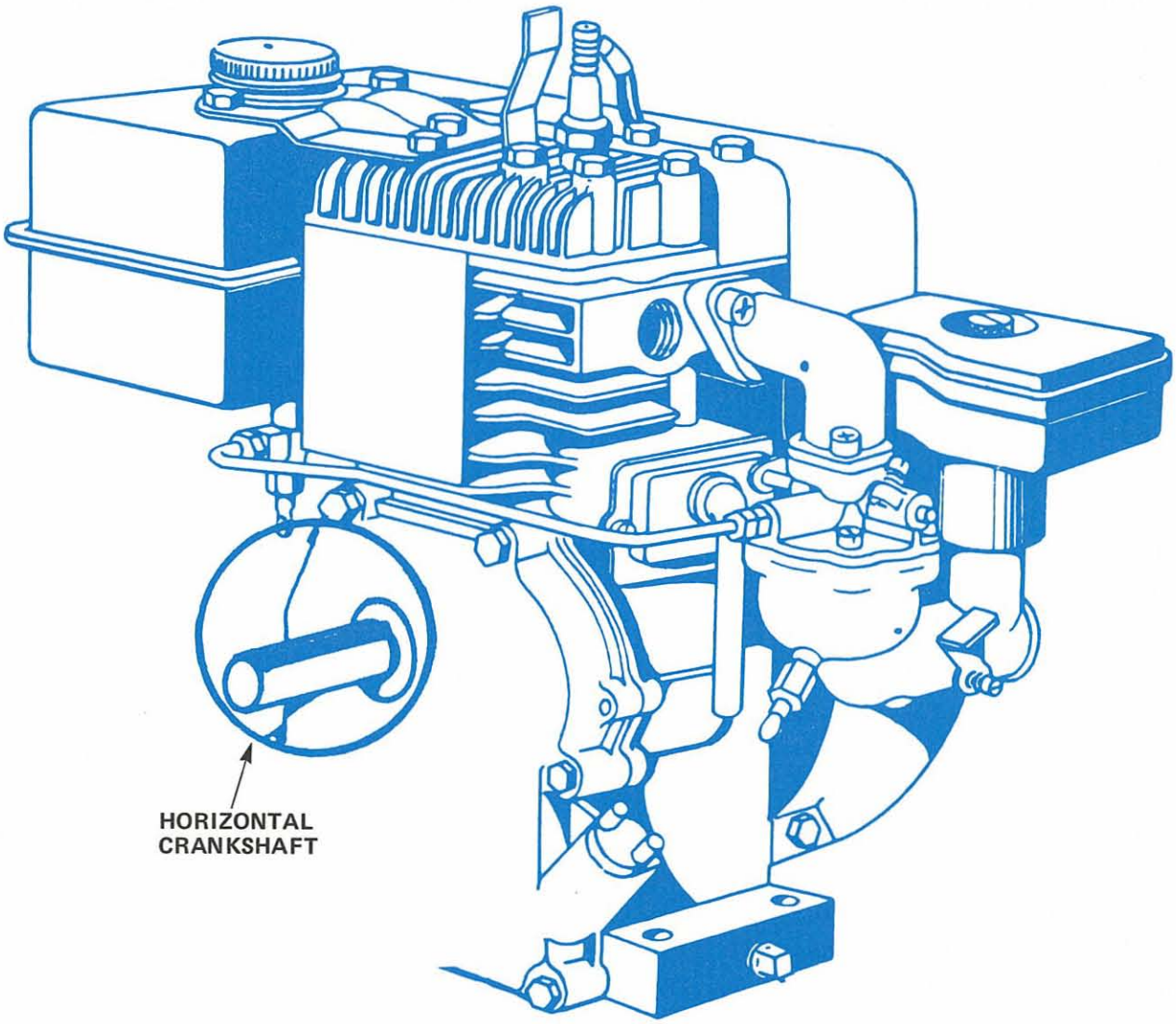


Figure 10

HORIZONTAL CRANKSHAFT ENGINES

The horizontal crankshaft engine may have its piston either in the vertical, horizontal or at some intermediate position. Figure 10 shows a typical horizontal shaft engine with the piston operating at a vertical position. Such engines as the automotive V-8 engines have pistons operating at an angle instead of vertical.

MULTIPURPOSE CRANKSHAFT ENGINES

The multipurpose crankshaft engine will operate in any position. The piston is at right angles to the crankshaft. The reason this type engine can be operated in any position will be explained later when we get into the study of the 2-Cycle engine. This type engine is often used on equipment requiring it to be used at extreme angles and sometimes even upside down. The chain saw is a typical application of this engine.

PROBLEMS WITH SMALL ENGINES

In spite of the popularity of small engines, they are often criticized unjustly. Their problems of not working properly are often due to lack of understanding of how the engine works and how it should be cared for and maintained. Most engine troubles are generally due to lack of proper service, operation, maintenance and repair. They are generally tougher than most people think and you'll usually find a simple reason for engines giving trouble. You should first examine the conditions under which the individual engine operates. Most small engines are designed to operate continuously at near top speed to prevent overload. No automobile engine could be expected to operate under these conditions so it is natural to expect small engines to be a little different in their starting and running habits. All functions must be operating at top efficiency at all times. There is generally very little power to spare so every bit of it must be put to use.

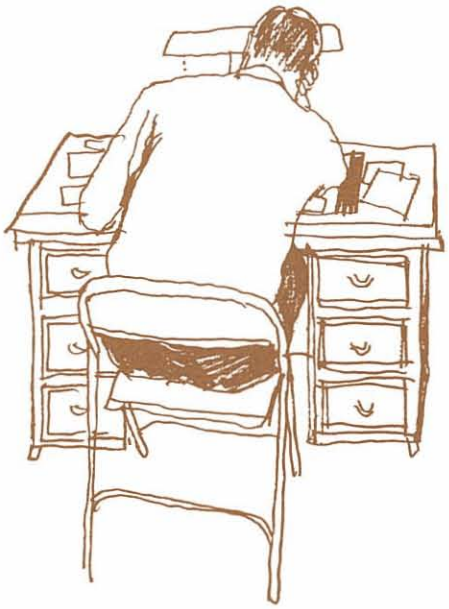
ENGINE ABUSE

The speed of the average small engine may be somewhere around 3600 R.P.M. This is equivalent to an automobile operating at over 80 miles per hour. This high R.P.M. is generally the continuous operating speed when being used. Some chain saw engines operate at over 7,000 R.P.M. to develop the required power.

During operation, small engines are often subjected to much abuse, overload and over-speeding. They are sometimes operated near ground level where dirt and dust are likely to get into their working parts. Often they are not serviced and cleaned properly causing rapid wear. Few small engines receive the proper servicing and maintenance that is given to other types of engines.

Because of the shortage of properly trained mechanics and service men, small engines are often not serviced properly. Actually small engine servicing and repair is quite simple but there has never been adequate educational facilities available. There have been a number of books written on the basic principles of small engines but most small engine mechanics have picked up their knowledge through trial and error and actual on-the-job training. Few mechanics know the actual operating principles of how these engines work.

What you will learn by studying small engines will also give you the basic knowledge of larger multi-cylinder engines. Regardless of the size engine, the principles of operation are the same. Operating, maintenance and repair procedures are very similar. If you understand small engines, you can apply this same basic knowledge to larger engines, such as automobiles and tractors.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

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- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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EXAMINATION ON LESSON 2
PRINCIPLES AND TERMS RELATING TO SMALL ENGINES

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ANSWER

1. The two cycle engine is lubricated by premixing oil with the fuel. _____
   TRUE
   FALSE

2. _____ is the normal operating horsepower of an engine. _____
   a. prony brake
   b. rated horsepower
   c. dynanometers

3. Power is the rate of _____ required to accomplish work. _____
   a. torque
   b. time
   c. displacement

4. _____ is the maximum horsepower that can be developed from an engine. _____
   a. horsepower variation
   b. prony brake
   c. brake horsepower

5. _____ is the number of times a force is multiplied. _____
   a. force
   b. mechanical advantage
   c. energy

6. _____ is a turning effort exerted on the output shaft of an engine when under load. _____
   a. momentum
   b. torque
   c. static inertia

7. _____ is the tendency of a object to remain at rest. _____
   a. momentum
   b. torque
   c. static inertia

8. _____ is the unit of measurement of power. _____
   a. torque
   b. momentum
   c. horsepower

9. The two cycle engine can be operated in any position. ____
   TRUE
   FALSE

10. One horsepower is capable of doing 33,000 foot pounds of work in two minutes. ____
    TRUE
    FALSE

11. An engine operated at maximum brake horsepower will have approximately 30% reserve horsepower for overload. ____
    TRUE
    FALSE

12. Mark as true or false the statement that applies to the engine shown in Fig. 2-1.
    a. Has more moving parts than any other type of engine. ____
    b. Can not be operated in an extreme angle position. ____
    c. Oil supply is suspended in fuel vapor. ____
    d. Requires separate oil system. ____
    e. Is a two cycle engine. ____
    f. Is a four cycle engine. ____
    g. Can be operated in any position. ____
    h. Is lubricated by premixing oil with the fuel. ____
    i. Is operated on straight fuel. ____

13. Mark the following statements true or false that apply to the engine shown in Fig. 2-2.
    a. Is operated on straight fuel. ____
    b. Has more moving parts than any other type of engine. ____
    c. Is lubriacted by pre-mixing oil with the fuel. ____
    d. Can not be operated in an extreme angle position. ____
    e. Is a four cycle engine. ____
    f. Oil supply is suspended in fuel vapor. ____
    g. Can be operated in any position. ____
    h. Is a two cycle engine. ____
    i. Requires a separate oil supply. ____

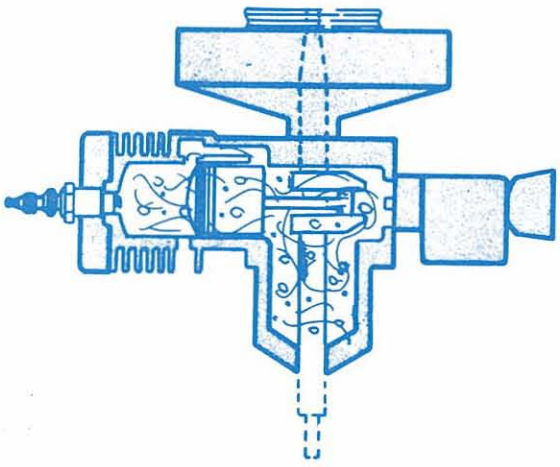

Figure 2-1
2 cycle engine

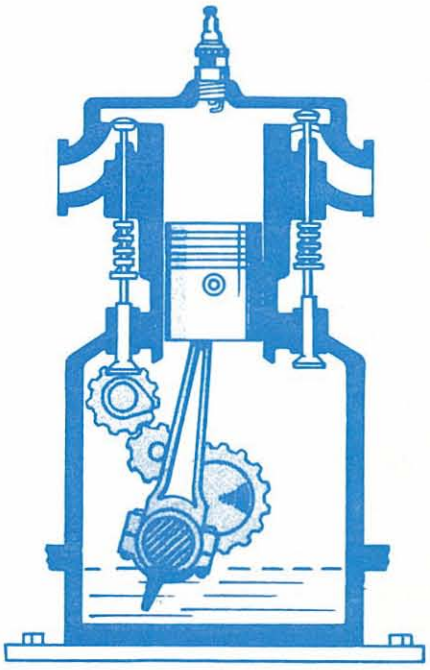

Figure 2-2
4 cycle engine

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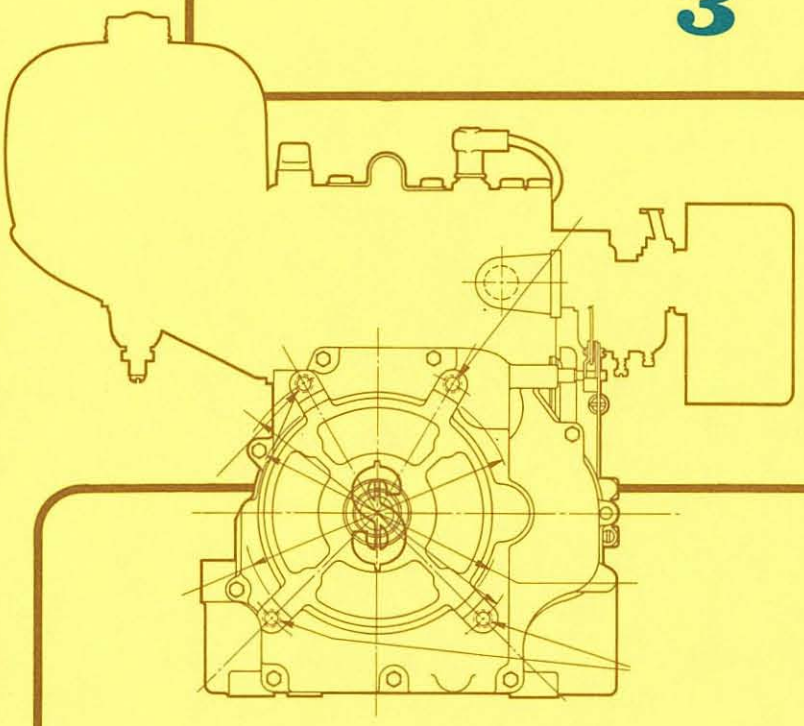
3



TURN THIS PAGE

INTRODUCTION TO SMALL ENGINE SERVICE

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CARE AND OPERATION OF SMALL ENGINES

To make small engines stand up under the heavy demands they are subjected to, manufacturers provide them with larger crankshafts, main bearings and larger oil supplies per horsepower than those in automotive engines. Most engines are built to government specifications which provide that the engine must be designed to operate under full load at its top speed for 1,000 hours. Some have been able to run much longer. A thousand hours is usually considered to be a long life for small engines operated on an irregular basis.

COMMON CAUSES OF OPERATING TROUBLES

Allowing dirt or foreign matter to enter the engine is one of the most common causes of engine failure. Lawnmowers and other equipment operating near the ground consistently have trouble from dirt entering the engine or carburetor. Failure to check the oil level in the crankcase is one of the main trouble areas of the 4-Cycle engine. If the engine oil level is low it will not lubricate properly and can cause minor and often severe damage. Overloading the engine will cause early breakdown and running the engine too fast will shorten the life of the engine. Most small engines are equipped with governors to control their speed for most efficient and safe operation. Often the governor can be changed or disconnected. This will allow the engine to operate at a higher R.P.M. but it will shorten the life of the engine considerably.

As a small engine specialist, you should be able to advise your customers on ways to save on maintenance and repair of his engine. The first and foremost rule for proper care and maintenance is to keep and read the Operator's Manual that comes with the engine. This manual gives important information for that particular engine and if the operator follows these instructions his engine will last much longer.

ENGINE IDENTIFICATION

There are two types of small engines that we will cover in detail later in the course. The 2-Cycle engine operates on the principle of both the fuel and lubricating oil being mixed together. The 4-Cycle burns straight gasoline as fuel and has a separate oil system to lubricate the engine. To get the proper parts for engine repair, it is necessary to know exactly what kind of engine the parts are needed for. There are many different manufacturers, engine sizes and other specifications that must be taken into consideration in order to get the right part. Parts may sometimes be interchangeable with different brand names. This is usually because they are the same basic engine design but sold to other companies under their own brand name.

When engines come from the factory, they have the necessary information to identify them and order replacement parts on a nameplate. If no nameplate is present it will sometimes be found stamped on the metal covering of the engine.

First we will need to know the name of the engine. This will generally be the name of the manufacturer but could also be the brand name under which the engine is sold.

Next is the model number of the engine. This number will usually give a clue as to the horsepower of the engine. Some model numbers refer to other information such as type of crankshaft and accessories or modifications. Sometimes very minor modifications are made in an engine during the production year or at some later date. Basically the engine is the same but possibly a new type of carburetion system was used on later models. This would make a complete new model engine even though everything else may be the same and interchangeable.

If a basic engine has a number such as TR-10-D and sometime later an improvement were made in the carburetion system the newer models may carry the number TR-10-E. If you ordered carburetor parts for the model TR-10-D and needed them for engine model TR-10-E, they very possibly would not fit. The manufacturer and parts supplier know from the model number what parts will fit the engine needing repairs.

As a further check, the serial number is necessary to insure the proper replacement part. This serial number tells the sequence in which the engine came off the assembly line. Sometimes modifications are made on the assembly line while the engines are in production. By knowing the serial number the manufacturer or parts dealer can tell which modification has been made. The proper parts can then be supplied. Sometimes there is a type number to identify engines which require certain parts and accessories which are different from the parts originally designed for the engine.

The specification number refers to the different designs requested by the equipment manufacturers that the engines are to be used with. The equipment the engine is to be used with may require a longer shaft or a special carburetor filter system. Many of the specification requirements are determined by the individual application the engine is to be used for.

The size is generally the bore and stroke of the piston or horsepower. The R.P.M. (revolutions per minute) is the rated engine operating speed. The type and specification information is included in the model and serial number on most engines.

OTHER NAMEPLATE INSTRUCTIONS

Other nameplate instructions often include such items as how to start and stop the engine. On a 4-Cycle engine the nameplate generally gives information on oil recommendations and other important information. This is just an abbreviated supplement to the Operator's Manual that goes with each engine.

USER SERVICING OF SMALL ENGINES

It is one of the responsibilities of the small engine repairman to advise his customers on methods of taking care of their engines. This is a service a customer will appreciate and should bring you much repeat business both from them and their friends.

It is a known fact that if you expect to get trouble-free service from an engine it must be serviced regularly. When this should be done varies with some manufacturers recommendations; the operating conditions under which the engine is used and the type of work it is to perform. There are three time periods when all small engines should be checked by the user or referred to the repairman. Before each operation, the operator should check the crankcase oil level in 4-Cycle engines and fill the fuel tank with clean, fresh, regular gasoline. High octane fuel is not recommended.

Be sure the proper gasoline and oil mixture is used and that it is mixed thoroughly. Mixing specifications are generally on the nameplate of 2-Cycle engines. Twenty-five hour inspection of the carburetor filter on all engines is necessary. Each 25 hours of use the crankcase oil should be changed on 4-Cycle engines. If the engine is operating under extremely dirty conditions, this 25 hour inspection should be done more frequently.

An annual inspection should be done by the small engine repairman. Customers will save money in the long run by bringing their engines in at least once a year for annual cleaning, inspection and tune-up. This would include fuel strainers, crankcase breather, points, condenser, new spark plugs and other minor adjustments.

2-CYCLE AND 4-CYCLE IDENTIFICATION

From the outward appearance of an engine, it may sometimes be difficult to determine whether it is 2-Cycle or 4-Cycle. There are three quick methods you can use to identify the engine. First check for an oil filler plug or cap located toward the lower part of the engine. If an oil filler plug is present the engine is 4-Cycle. If the nameplate gives oil specifications for crankcase oil the engine is 4-Cycle. If it gives information on mixing fuel and oil the engine is 2-Cycle. After you have worked with small engines for a short time you will find it quite easy to identify them.

HOW SMALL ENGINES ARE COOLED

Most small engines, particularly the ones used on lawnmowers, motorcycles and garden tractors are air cooled. Most all major brand outboard motors are water cooled engines. However, in recent years some outboard engines are air cooled. An air cooled engine depends on the flow of air around the engine to take away the heat generated by the moving parts of the engine. In order for this heat to dissipate it is necessary that the engine be kept clean and have a constant movement of air.

To accomplish this metal shrouds or cover plates are positioned around the engine to deflect the movement of air. The average temperature of the burned gases inside the cylinder reaches to about 3,600 degrees. This extreme heat must be given off through the cooling system to keep the engine parts from melting. Figure 11 shows a cross section of a typical cylinder head. The piston operates in the area at A-1 and creates this extreme heat by compressing and igniting the fuel mixture. The outside of the cylinder wall, shown at A-2, absorbs part of the heat. About one-third of the heat is exhausted through the exhaust system. One third is used to develop the power the engine generates and the other one-third is given off through the cooling system.

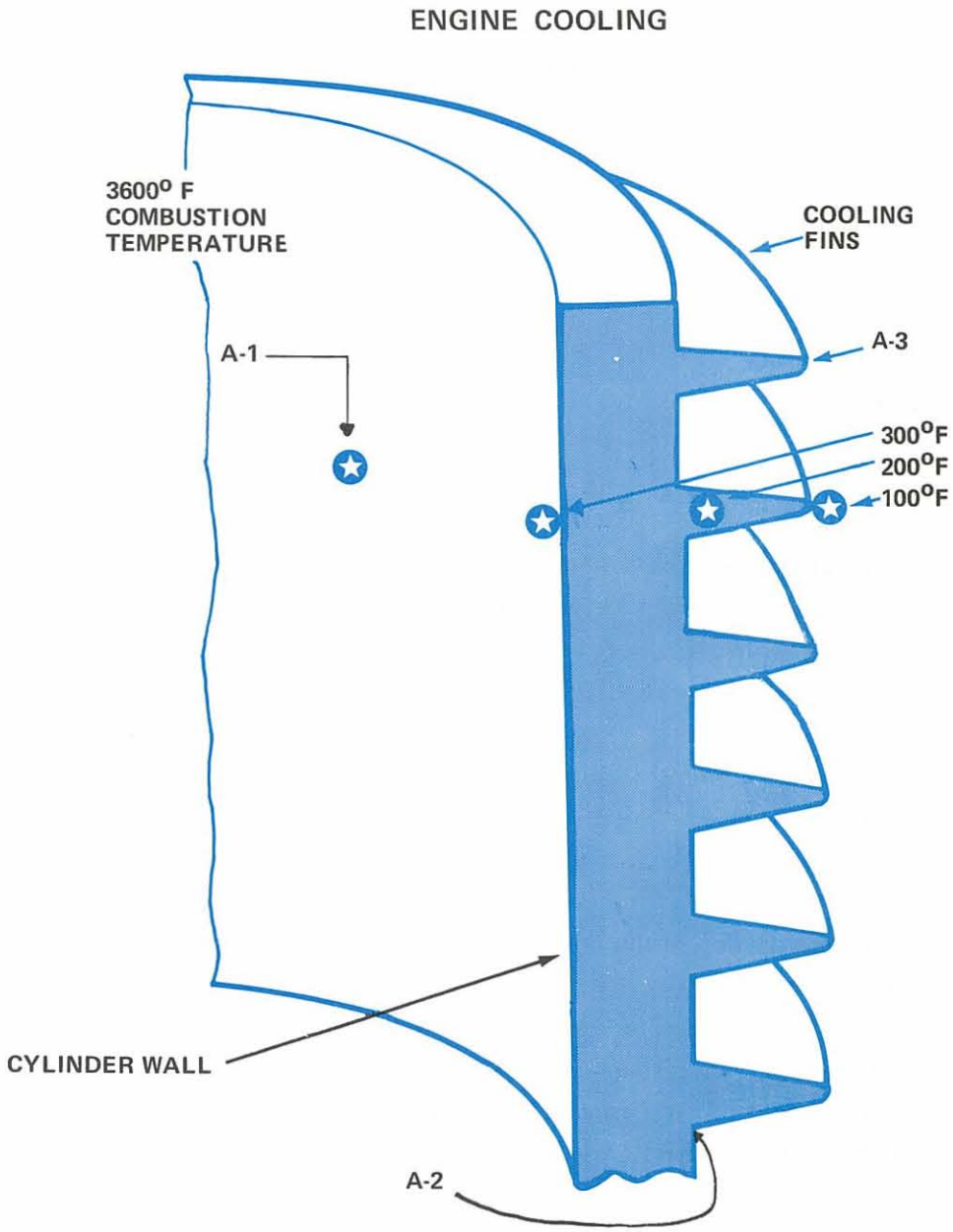

Figure 11

CONDUCTION AND CONVECTION

Conduction is a term used to describe the transfer of heat through a solid conductor such as the cylinder wall of an engine. Convection is the term used to describe the transfer of heat through the movement of gases or air. When air is heated it becomes less dense and raises. Other cool air then moves in to replace it. Forced convection is used to speed up the cooling process. By the addition of a fan and baffles the air flow is increased. Cooler air is forced past the cooling fins shown at A-3 and removes the hot air from around the engine.

PARTS OF A COOLING SYSTEM

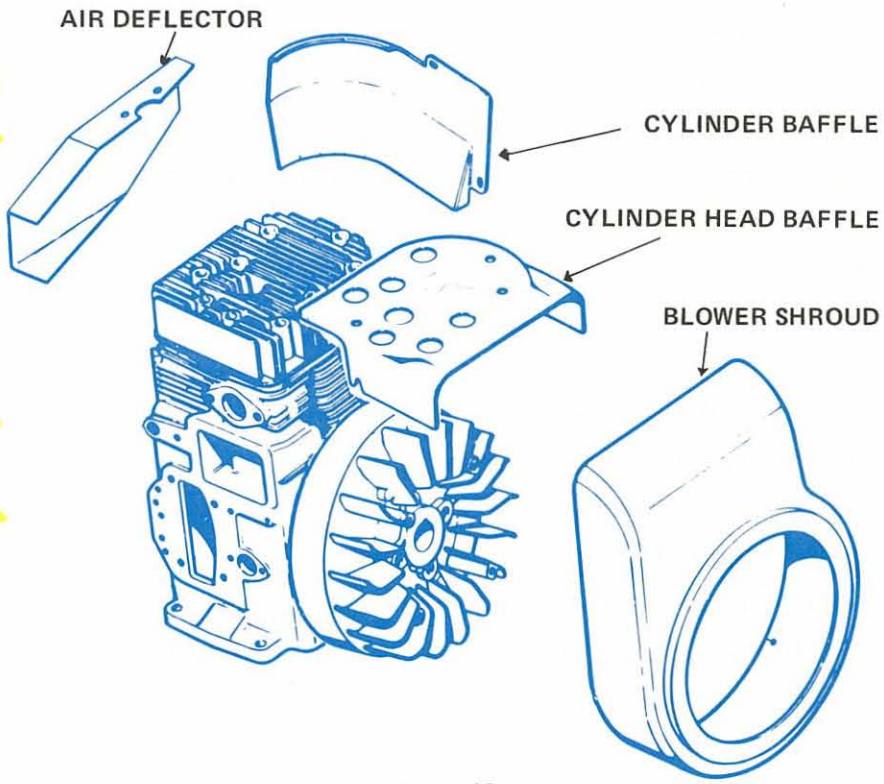

Figure 12

This forced convection is accomplished by a flywheel blower forcing air past the cylinder wall and the cooling fins. It is directed around the cylinder by the cylinder baffles.

Figure 12 shows a typical arrangement of these baffles. They are designed so air is directed around the critical heat-giving parts of the engine. These baffles are sometimes thought of as "guards" or some other non-functional part of the engine. They are very important and the engine should never be operated without them. The air flow will not be adequate and the engine will overheat in a very short time if operated without these baffles.

Air baffles are not necessary on water cooled engines. Water has a much higher efficiency than air to dissipate heat from an engine. Some air cooled engines, such as the one used on motorcycles, require very little, if any, baffles in their cooling system because they depend on air flow past the cooling fins by movement of the machine through the air.

Motorcycles and other engines used on similar applications will overheat if operated in a non-moving condition for a prolonged length of time. It is very common for a motorcycle engine to develop a dangerously high engine heat when operating for a long period of time in a stationary operation or in very slow traffic. The heat will not be dissipated fast enough because the outside air is not removing heat from the fins.

IMPORTANCE OF CLEANING

One of the most important things in getting maximum engine life from a small engine is keeping it clean. Engine operators will often be very particular in using the proper fuel mixture, oil change and other regular maintenance but overlook keeping the engine clean. Overheating is often caused by dirt and grime on the outside of the engine and by a clogged or restricted exhaust system.

Dirt and grime are very poor conductors of heat and will seal heat in the engine. They act just like an insulator and will not allow the heat to dissipate.

A clogged muffler will also cause an engine to overheat. It creates a back pressure in the cylinder and restricts the hot gases from escaping. Since one-third of the engine heat is given off through the exhaust system, this can cause the engine to overheat very quickly.

If dirt is allowed to enter inside the engine it can cause rapid wear on all moving parts. In addition to being an insulator, dirt also acts as an abrasive and will cause excessive wear on all moving parts. Dirt can enter when you check the crankcase oil level, it can get into the air cleaner assembly when the filter is removed.

One big advantage of cleaning an engine regularly is to reveal any hidden weak points or defects. When gasoline or oil collects on rubber parts such as the insulation on spark plug wires, V-belts or rubber hoses it causes them to soften and deteriorate. Dirt and grime will often cover broken or damaged parts. These parts can be replaced before serious damage results from further use. Many shops will completely clean an engine before beginning to service them. This is a very good habit to get into and will generally reduce the repair job time considerably. It is much easier and faster to work on a clean engine than one covered with dirt and grime.

CLEANING TOOLS AND MATERIALS

Most any well operated shop will have a place set aside just for the cleaning operation. It is best to have a separate set of tools and equipment set aside in this area just for the cleaning operation. For most small engines the following tools and equipment should be adequate for the cleaning operation:

1. Slot-head screwdriver, 6-inch.
2. Phillips head screwdriver, 6-inch.
3. Socket Set – including 3/8", 7/16", 1/2", 5/8" and 9/16" sockets.
4. Open end wrenches, same size.
5. Wire brush.
6. Solvent container, 2-gallon.
7. Paint brush, 1/2" to 2".
8. Water hose and nozzle.
9. Putty knife, 3/4".
10. Small stiff brush, such as tooth brush.
11. Commercial solvent degreaser. This is commonly called "gunk" and is available at most automotive supply stores. Do not use gasoline.
12. Hand sprayer.
13. Cleaning pan, 8" x 4" x 3" deep.

A fire extinguisher is a must in any engine repair shop. The presence of fuel always presents the possibility of fire. The extinguisher should be of the dry chemical, carbon dioxide, or foam type. These three types of fire extinguishers are most effective for gasoline or other petroleum-type fires.

An air compressor is one of the handiest pieces of equipment in most any shop. It is very helpful in removing dirt from hard-to-reach places.

BASIC PRINCIPLES—INTERNAL COMBUSTION ENGINE

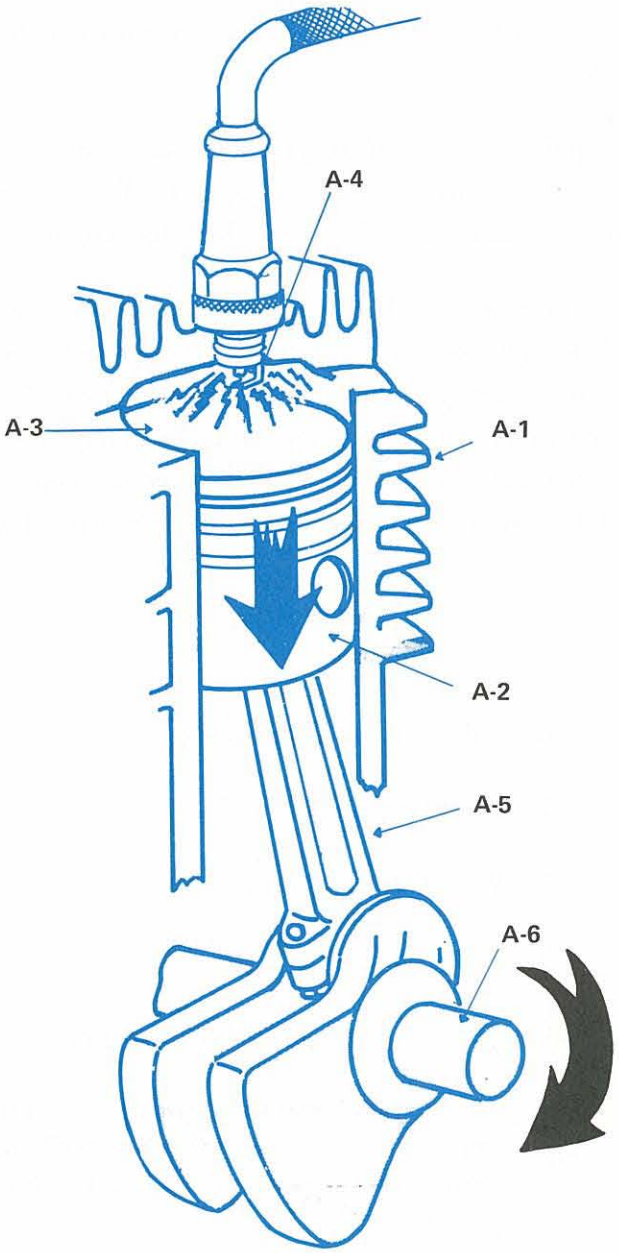

Figure 13

SMALL ENGINE OPERATION

The small air-cooled gasoline engine is known as an internal combustion engine. The engine gets its energy or power to drive the crankshaft by a series of explosions generated within the engine itself.

Figure 13 shows the basic principle of the internal combustion engine. The cylinder shown at A-1 contains the piston shown at A-2. The piston is forced to make a downward travel because of the fuel and air mixture igniting in the top of the cylinder as shown at A-3.

The fuel and air mixture is brought under pressure by the piston and then ignited by the spark plug shown at A-4. This causes an explosion forcing the piston back down. The piston itself always travels in a straight line.

The top part of the rod shown at A-5 is connected to the piston and the lower part is connected to the crankshaft shown at A-6. The crankshaft is offset at the point the rod is connected to it. As the piston moves up and down it changes the straight line motion of the piston to a rotary motion on the crankshaft.

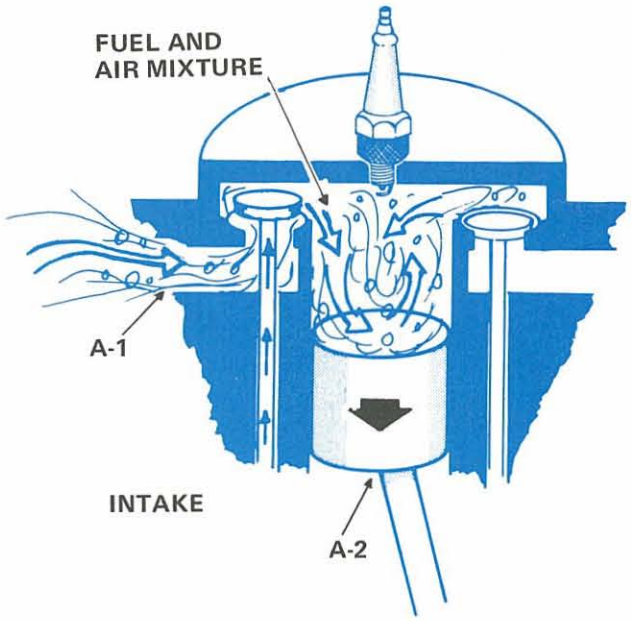

Figure 14

In order to make an engine run continuously there are four different events that must take place. Failure of any of these events will not complete the series and the engine will not run. These four events are called strokes or cycles.

Intake is the first of the four steps. Figure 14 shows the piston traveling on the down or intake stroke. As it travels down a suction is created drawing fuel and air mixture into the cylinder as shown at A-1. The valve is open allowing fuel and air to enter. Note, the piston shown at A-2 is traveling down and suction brings in the fuel air mixture into the chamber.

Compression of the fuel air mixture is the second event in the cycle. Figure 15 shows the piston traveling up. Note both valves shown at A-1 and A-2 are closed. As the piston moves up it begins to compress the fuel and air mixture contained in the area shown at A-3. As the fuel and air is compressed it becomes highly explosive. With both valves closed the fuel and air mixture cannot escape.

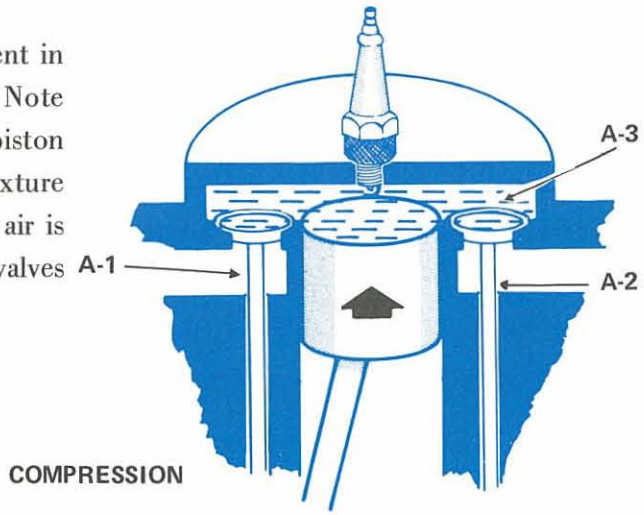

Figure 15

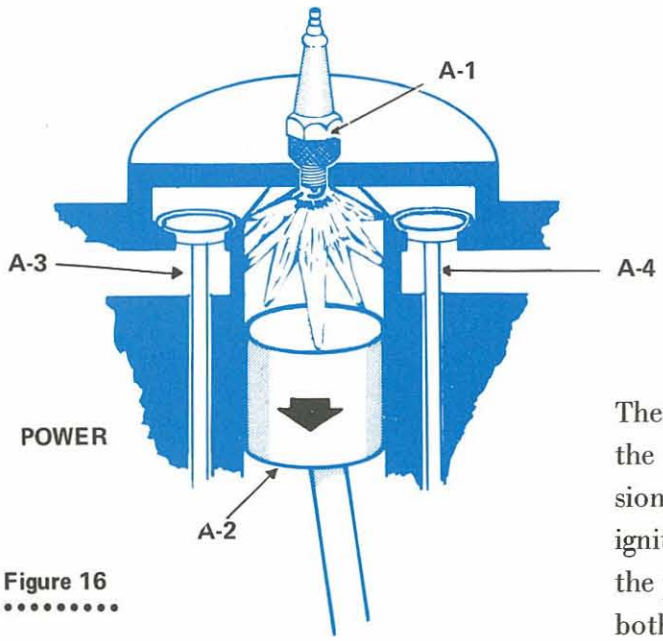

Figure 16

The next event is the Power stroke. As the piston reaches the top and has the fuel and air mixture under compression, the spark plug shown at A-1 in Figure 16 fires and ignites the fuel and air mixture. The explosive force moves the piston shown at A-2, in the downward direction. Note, both valves shown at A-3 and A-4 are still closed.

The last event to take place is the exhaust stroke shown in Figure 17. After the piston reaches the bottom of the stroke it begins moving upward again. At this point the exhaust valve shown at A-1 is open and allows the burned gases to escape. The intake valve at A-2 is closed.

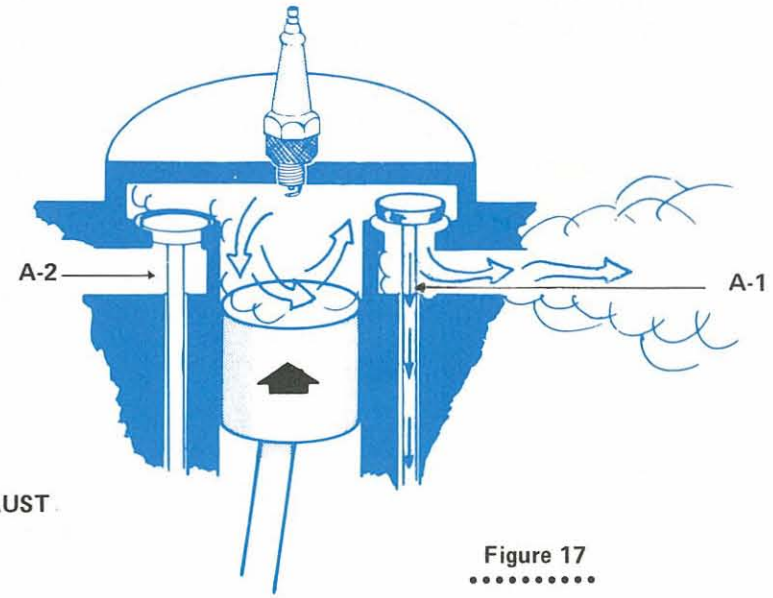

Figure 17

The completion of this series of events is called the engine cycle. When the first cycle is completed the second cycle begins and then the third and continues as long as the engine is running.

The full travel of the piston in one direction, either toward or away from the top of the cylinder, is called a stroke.

Some engines complete a cycle during one revolution of the crankshaft. This would be two strokes of the piston. These engines are called 2-stroke engines or 2-cycle engines. Others are designed to require two revolutions of the crankshaft or four strokes of the piston to complete the cycle. These engines are called 4-stroke or 4-cycle engines. We will go more into their functions just a little later in the course.

SPECIAL NOTICE

Beginning with lesson 5 we will begin covering in detail different parts of an engine and its component parts, such as the carburetor, starter, fuel and electrical system. Later in the course you will receive a new 4 H.P. 4-cycle engine to work on. You will completely disassemble this engine, examine all the parts and reassemble it ready for operation. As you go through the course, it would be a good idea to obtain an old engine to take apart as you are studying the different components that make up a complete engine.

You can obtain these junk engines from most lawnmower rental agencies, repair shops, garage sales and often from your friends and neighbors. It would be best to use a 4-cycle engine since they have many more moving parts than the 2-cycle. As you progress through the course you should begin taking this engine apart as the lessons cover that particular part of the engine operation.

Actual hands-on working experience with an engine as you are studying that particular phase will help you to understand the operating principles of small engines.

The tools you will receive with this course will be adequate to completely disassemble and reassemble both the old engine and the new one you will receive later. Generally the easiest engines to obtain are from old lawnmowers. Often these engines are still in repairable condition and you will be able to rework the engine to good operating condition and resell it later for several times the amount you paid for it. If the engine is beyond repair you can salvage some of the parts for repair of other engines you will be working on later.

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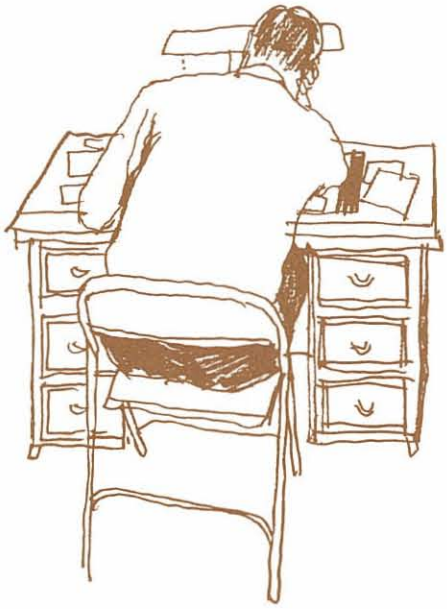

This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.___ (Fill In)

LESSON NO.(S) _ (FILL IN) ___ ___

HOMEWORK ASSIGNMENT

(Leave Blank) GRADE ___ . ___

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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NAME _____ Student No _____
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ADDRESS _____ Date _____

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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter In under the ANSWER column. If it Is a TRUE or FALSE question, write in T or F under the ANSWER column. I he first question has been worked out for you as an example.

ANSWER

1. Metal shrouds are positioned around the engine to deflect the movement of air. _____
   TRUE
   FALSE

2. Failure to check and maintain _____ in a four cycle engine is one of the main trouble areas. _____
   a. gas
   b. oil
   c. spark plugs

3. Some of the information for ordering replacement parts is name of the unit, the model number, and serial number. _____
   TRUE
   FALSE

4. Dirt and foreign matter entering the engine is one of the most common causes of engine failure or wear. _____
   TRUE
   FALSE

5. The time period when all small engines should be checked either by the operator or service man are before each operation, a twenty-five hour inspection, and an annual inspection. _____
   TRUE
   FALSE

6. _____ is the term used to describe the transfer of heat through the movement of air. _____
   a. conduction
   b. convection
   c. fuel-air mixture

7. If an engine does not develop enough power for satisfactory operation the governor should be disconnected. _____
   TRUE
   FALSE

8. Fuel and air mixture is brought under compression by the _____. _____
   a. spark plug
   b. crankshaft
   c. piston

(Continued on page 2)

9. Information to identify an engine for replacement parts should be found on the name plate. _____
   TRUE
   FALSE

10. About _____ of the engines heat is given off through the exhaust system. _____
    a. 1/4
    b. 1/8
    c. 1/3

11. _____ energy is contained and not in action. _____
    a. kinetic
    b. potential
    c. mechanical advantage

12. _____ is the term used to describe the transfer of heat through a solid material. _____
    a. conduction
    b. convection
    c. resistance

13. If the name plate give specifications for crankcase oil, it is a two cycle engine. _____
    TRUE
    FALSE

14. The full travel of the piston in one direction is called a _____. _____
    a. bore
    b. piston
    c. stroke

15. Mark the following statement either True or False that apply to the parts of the cooling system shown in Fig. 3-1.
    a. air deflector
    b. blower shroud
    c. cylinder head baffle
    d. cylinder baffle

16. Mark the following statements as True or False as they pertain to the action or parts of the engine principles shown in Fig. 3-2.
    a. fuel
    b. spark plug firing
    c. cylinder or fins
    d. crankshaft
    e. rod
    f. camshaft

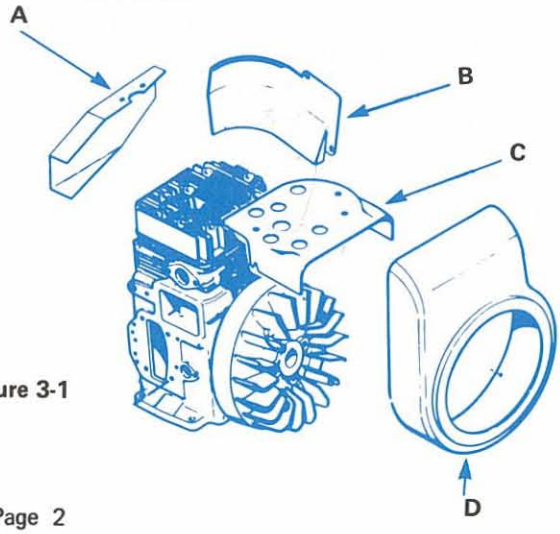

Figure 3-1

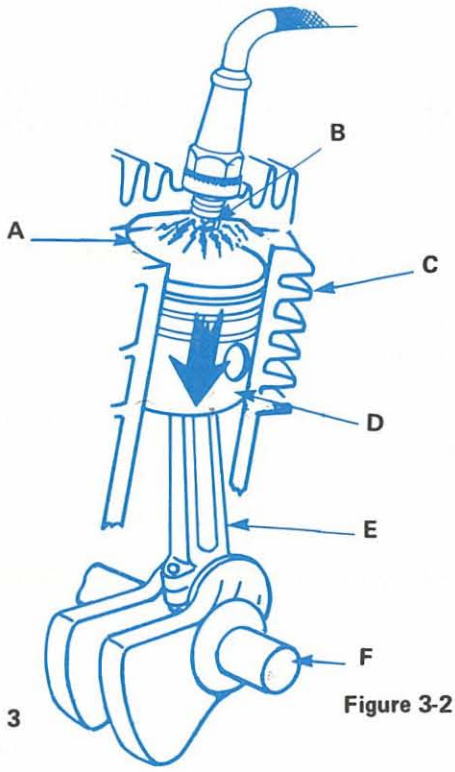

Figure 3-2

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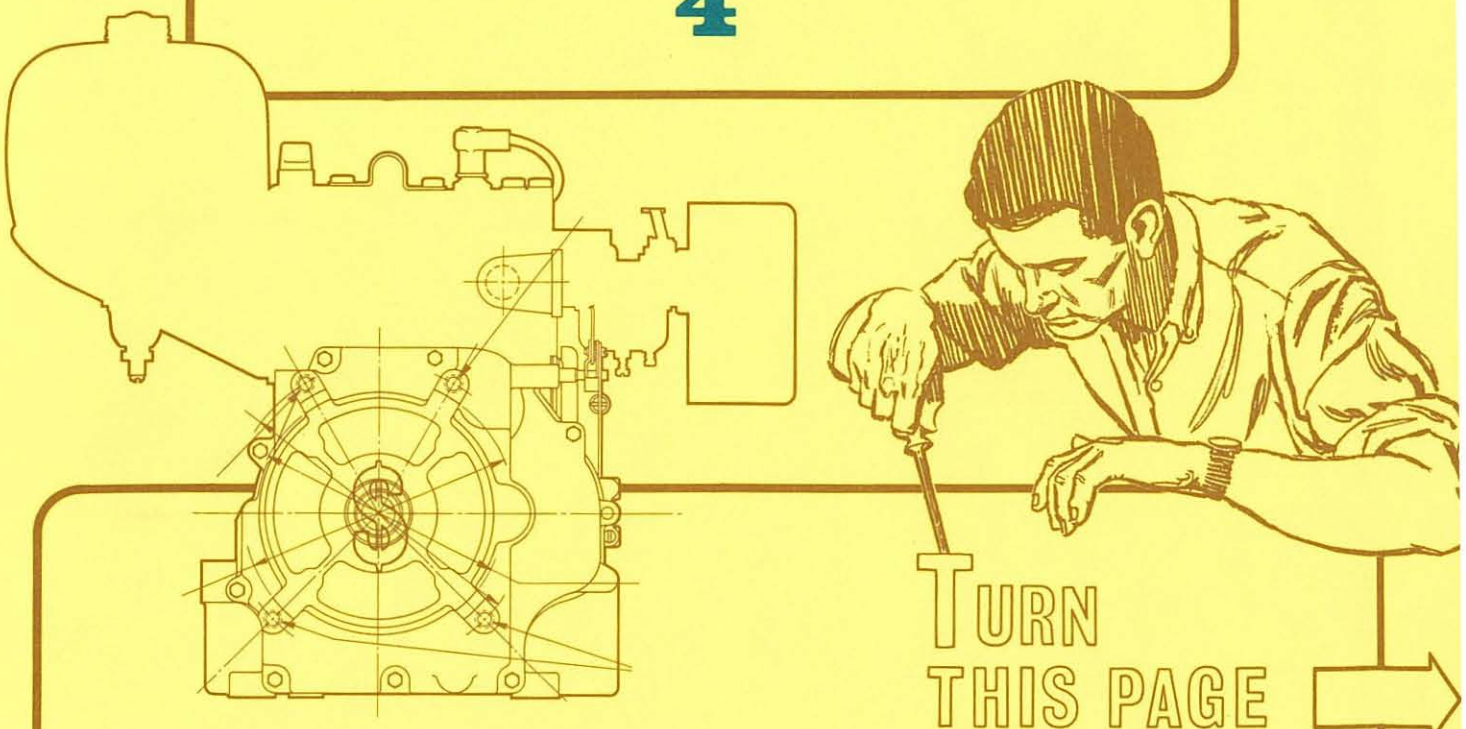

TURN THIS PAGE

...and let's find out all about --

TWO AND FOUR CYCLE BASIC PRINCIPLES

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4-CYCLE BASIC OPERATION

The operation and theory of the 4-cycle engine is similar to the general classification of small engine operation we have just covered except we will go further into detail of all the functions. The four strokes or cycles this engine must go through are intake compression, power and exhaust. When these phases have been completed they start over again if the engine is to continue to run.

Figure 18 shows a typical 4-cycle engine. The crankshaft is shown at A-1. This transmits power and work direct to the piece of equipment being operated. As the piston shown at A-2 moves up and down, it moves the rod shown at A-3. This rod is connected to the crankshaft. As the rod goes up and down the crankshaft turns. A gear, shown at A-4, is connected to the crankshaft and turns as the crankshaft rotates. This is a small gear.

Another larger gear, shown at A-5, meshes with the small gear on the crankshaft. This gear is attached to another shaft shown at A-6 which is the camshaft. As the crankshaft turns the gears A-4 and A-5 turn the camshaft shown at A-6.

The small gear on the crankshaft at A-4 must make two complete turns in order for the larger gear at A-5 to make one complete turn. Attached to the camshaft, there are two cams shown at A-7. These cams are offset or eccentric. As they rotate the intake valve at A-8 and the exhaust valve will move up and down.

The flywheel shown at A-9 is connected to the crankshaft and contains the magneto and other electrical functions of the engine. Later we'll go into detail on all the parts of the 4-cycle engine and how they relate to one another. One important thing to remember is the 4-cycle engine uses unmixed fuel and has a crankcase for oil lubrication of the moving parts.

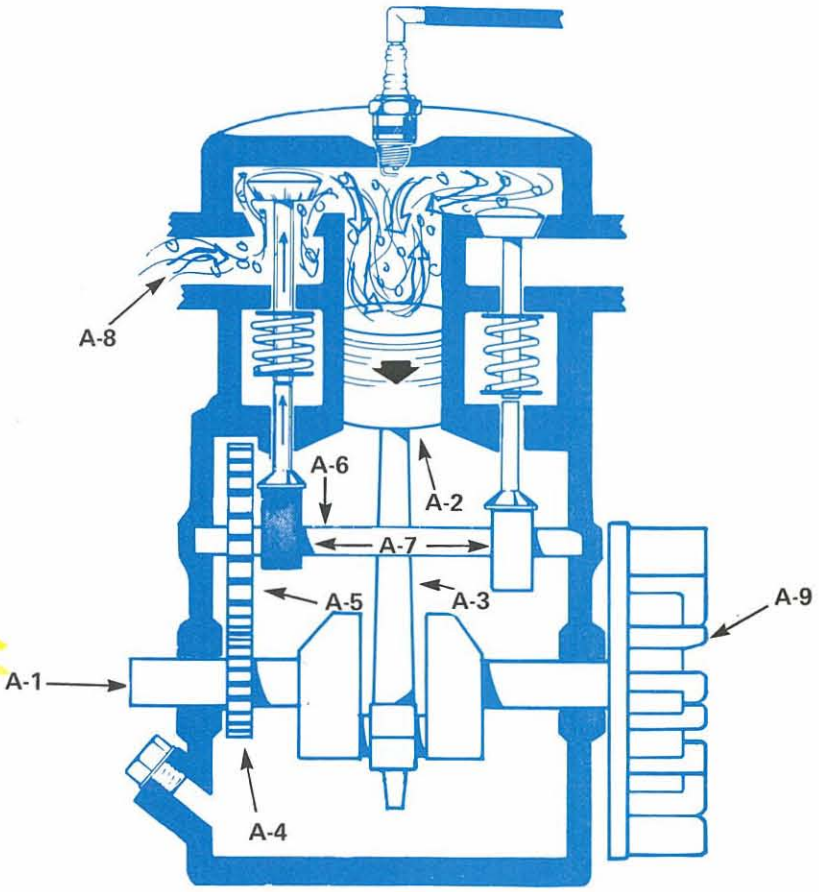


Figure 18

2-CYCLE BASIC OPERATION

The basic operation and theory of the 2-cycle engine is different than the 4-cycle in that it has only one valve and no crankcase for oil to lubricate the engine. It has no camshaft and cannot be operated with regular fuel.

Figure 19 shows a typical 2-cycle engine. Point A-1 is the crankshaft that transmits power and work direct to the equipment being operated. As the piston A-2 moves up and down it turns the crankshaft the same as the 4-cycle engine, but here the similarity ends.

There is a valve shown at A-3. This is called the reed valve and is always located between the engine and the carburetor. As the piston moves up this valve opens and fuel is sucked into the area shown at A-4. At the same time fuel and air mixture is compressed in the top of the cylinder and ignited.

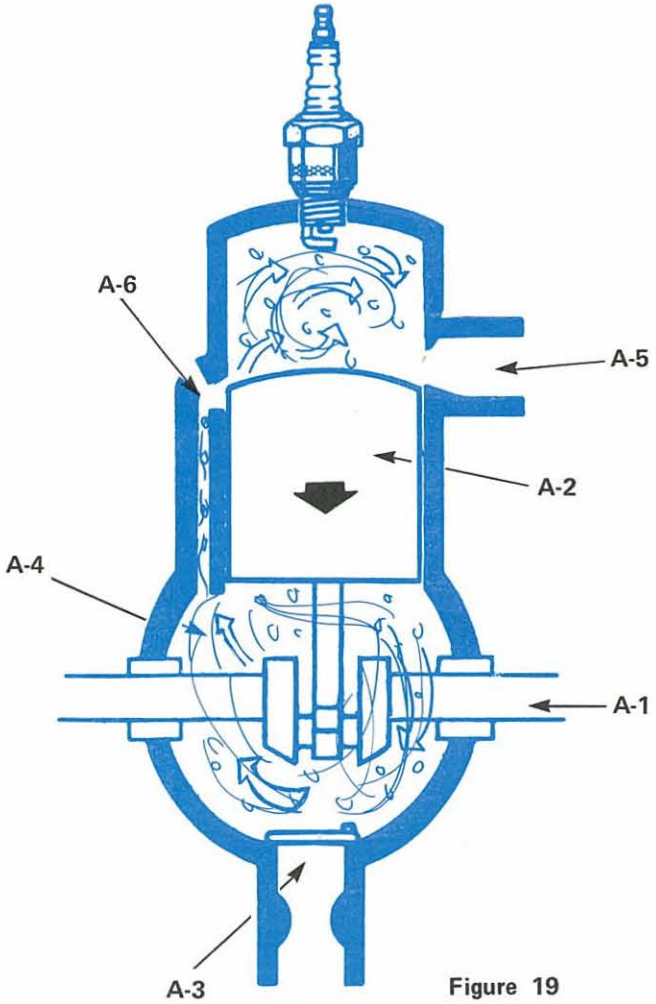


Figure 19

The spent gases are expelled out the exhaust port shown at A-5 and new fuel and air mixture is sucked in from the bottom through the port or opening shown at A-6. The cycle is then repeated.

2 cycle lubrication

Since there is no oil reservoir for lubrication like the 4-cycle engine the fuel must be mixed with oil for lubrication. The fuel and oil mixture enters the bottom of the engine and goes up the piston walls and out the top part. All moving parts are exposed to the fuel and oil mixture for lubrication. There are many less moving parts in the 2-cycle engine and it would appear that there would be less possibility of trouble, however, this advantage is offset by the higher speed necessary for maximum power.

On 2-cycle engines every down stroke is a power stroke. The spark plug fires igniting the fuel air mixture on every down stroke. Every revolution of the crankshaft is a power stroke.

On 4-cycle engines every second down stroke is a power stroke. They fire every second revolution of the crankshaft. The crankshaft must make two complete revolutions each time the spark plug fires.

CYLINDER PISTON AND ROD ASSEMBLIES

The function of the cylinder, piston and rod assembly of an engine is to change chemical energy into mechanical energy. The chemical energy is obtained from the fuel used to operate the engine. When a spark is used to ignite the fuel mixture an explosion occurs and creates chemical energy. This chemical energy is then converted into mechanical energy through the action of the piston and rod.

Figure 20 shows a typical cylinder, piston and rod assembly. Power is developed in the cylinder A-1 and transferred through the piston shown at A-2, and through the rod shown at A-3. The rod is connected to the offset part of the crankshaft. The piston works just like a pump on the intake, compression and the exhaust strokes and turns the crankshaft shown at A-4.

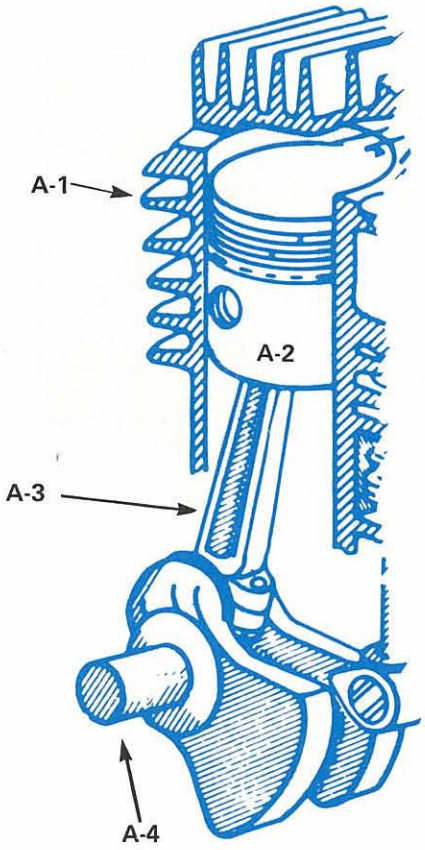


Figure 20

Figure 21

Figure 21A

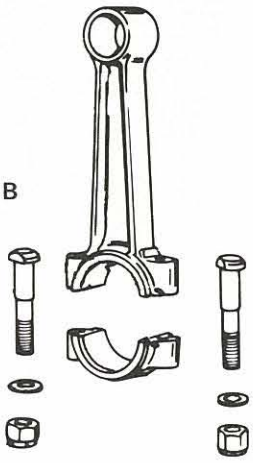


Figure 21B

Figure 21 shows the complete piston, rod and ring assembly in the order in which they are related to each other. This assembly can be divided into two sections. The piston assembly is shown at 21A and the rod assembly is shown at 21B.

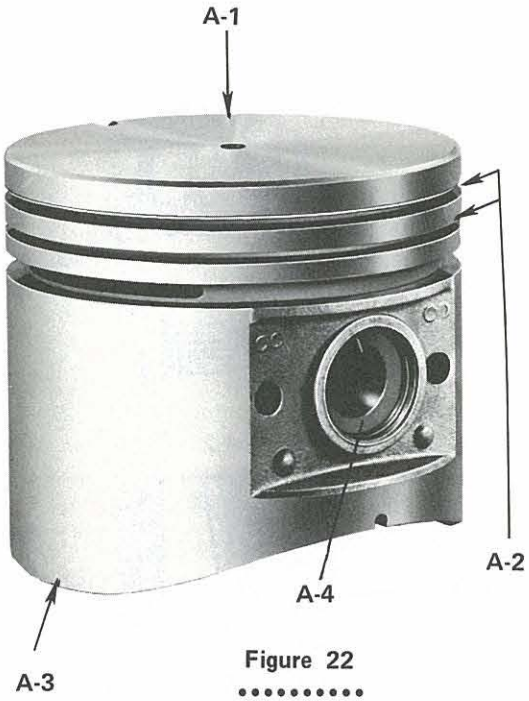


Figure 22

PISTON ASSEMBLY

The piston assembly consists of the piston, rings and wristpin assembly. Figure 22 shows the piston itself and its parts. The top, shown at A-1, is called the head. This is the part that reaches the top of the cylinder and receives the explosive force from the spark plug igniting the fuel and air mixture.

The areas shown at A-2 are the grooves for the rings. The body or bottom part of the piston shown at A-3 is called the skirt. There is a hole through the piston as shown at A-4 that contains the piston pin, commonly known as the wristpin. This pin assembly is shown at point A-1 in Figure 21A. It connects the piston to the rod assembly.

TYPES OF PISTONS

Pistons in 4-cycle engines appear to be the same size or diameter from top to bottom but, if measured carefully, they often are not. Sometimes they are tapered toward the top of the piston. They are actually smaller in diameter at the top part of the piston than the lower part around the skirt. This difference is so small it would be difficult to measure. The top or head of the piston is generally flat on most 4-cycle engines.

Pistons used in 2-cycle engines may often be tapered or they may be the same diameter from top to bottom.

Figure 23 shows the two different pistons used in 2-cycle engines. The piston shown at A-1 has a raised portion, or baffle on top. This type piston is used with the cross scavenge system. The loop scavenge system shown at A-2 uses a flat top piston. All pistons have grooves for rings.

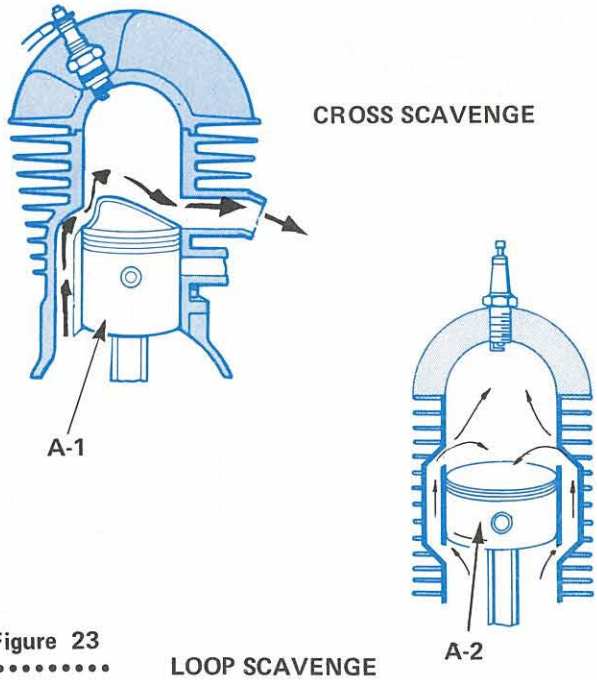


Figure 23

RINGS

There are three basic types of rings used in most 4-cycle engines. Figure 24 shows the location of these three types of rings. The top two rings, shown at A-1, are the compression rings. These are designed to make a tight seal between the piston and the cylinder wall. This is very important during the power stroke to keep the exploding gases from being forced into the crankcase by the piston which results in a loss of power.

Compression rings are always installed in the top grooves on all 4-cycle engines. The ring located at A-2 is actually the second compression ring but it sometimes has a slight bevel to help distribute oil on the cylinder wall.

The oil ring is located at A-3 and is designed to distribute oil along the cylinder walls. This ring has very little to do with the compression of the engine.

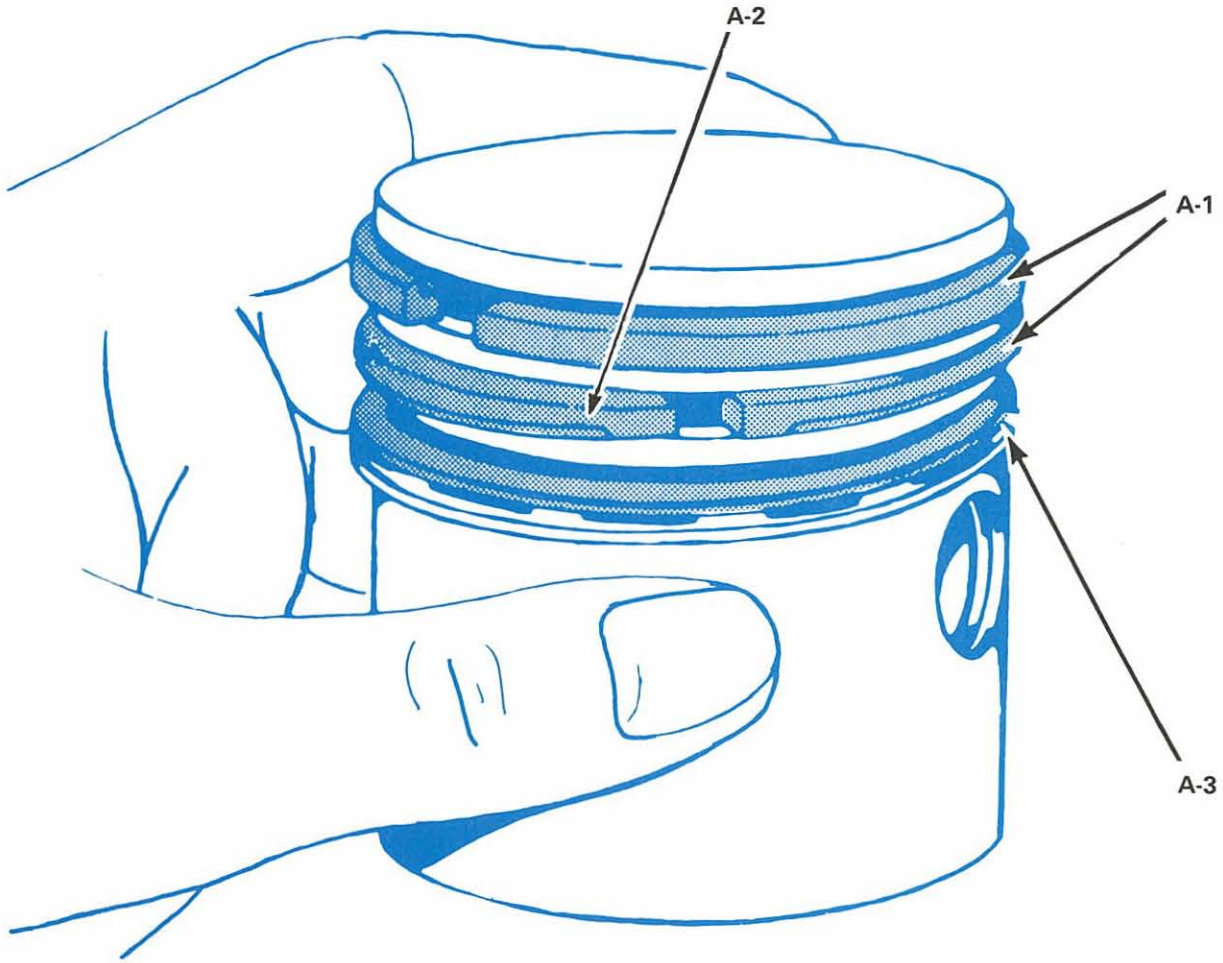
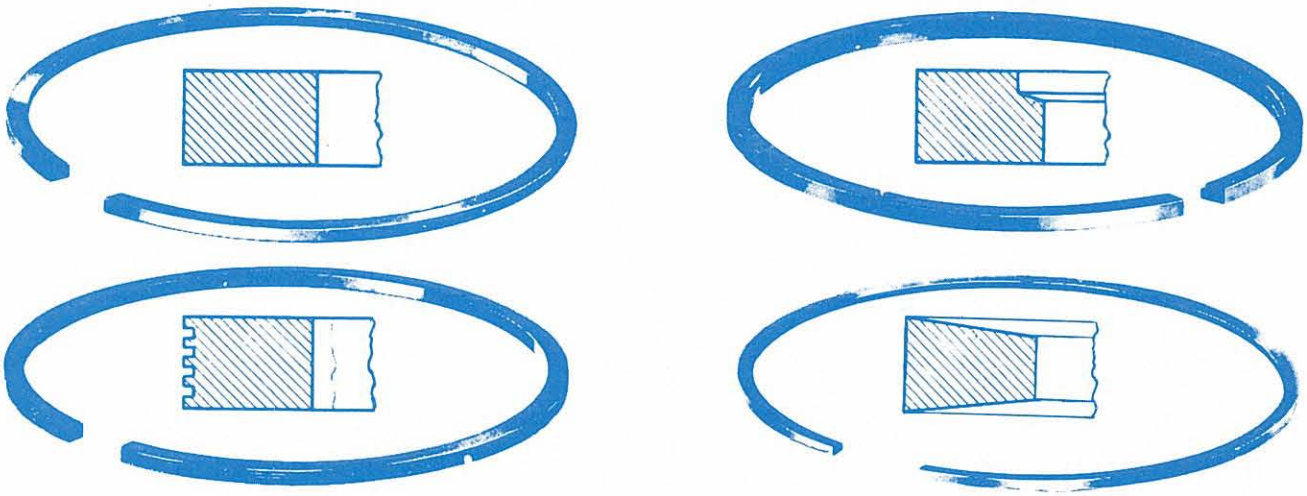


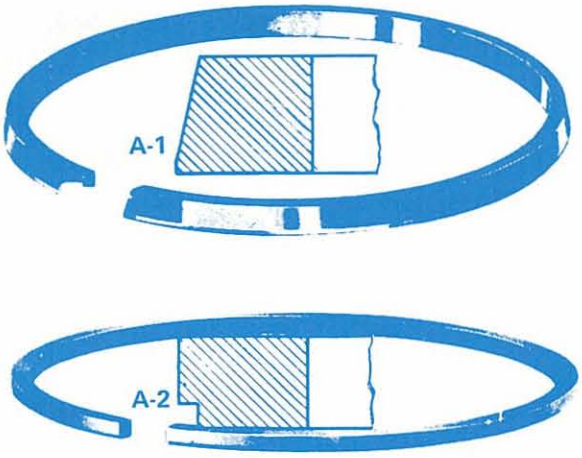
Figure 24

Rings are not all made alike. Different engineering principles have been applied by different manufacturers. Figure 25 shows the different types of compression rings used and how they can vary in design and appearance. Compression rings are designed to make a tight seal between the cylinder and the piston. As these rings wear, or the cylinder wall wears, combustion gases will seep through the space between the rings and the cylinder walls and result in loss of compression which will reduce the power of the engine. These are always in the top grooves of the piston.



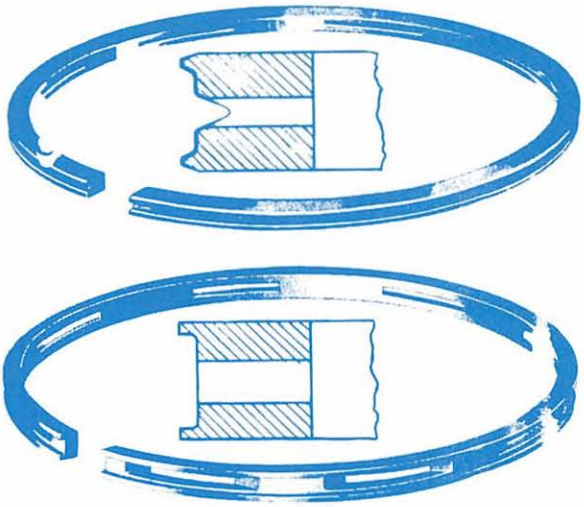
COMPRESSION RINGS

Figure 25



OIL SCRAPER RINGS

Figure 26



OIL CONTROL RINGS

Figure 27

The rings shown in Figure 26 are called oil scraper rings or oil wiper rings. They are designed to wipe the excess oil off of the cylinder wall as the piston moves down. Note the bevel shown at A-1 and the notch shown at A-2. This allows the rings to wipe off excess oil and still give some degree of compression.

Oil control rings are shown in Figure 27 and are located under the compression rings toward the skirt or bottom part of the piston. These rings regulate the amount of oil going to the compression rings in the cylinder walls. Some engines have additional expander rings that are located between the oil control rings and the pistons.

Figure 28

Figure 28 shows the design of these ring expanders. The expander ring helps maintain the tension of the oil control ring as it begins to wear. The expander ring also helps the oil ring take the shape of the cylinder walls as it becomes slightly out of round. Remember, 2-cycle engines do not have oil rings because the fuel and oil is mixed together.

Let's take a little closer look at just how the rings function inside the cylinder walls. If the piston is to perform effectively inside the cylinder a number of critical tolerances must be met. The rings must seal properly to keep the combustion gases out of the crankcase and prevent blow-by. Very often when new rings are installed an engine will use some oil during the time necessary for the rings to break in or seat.

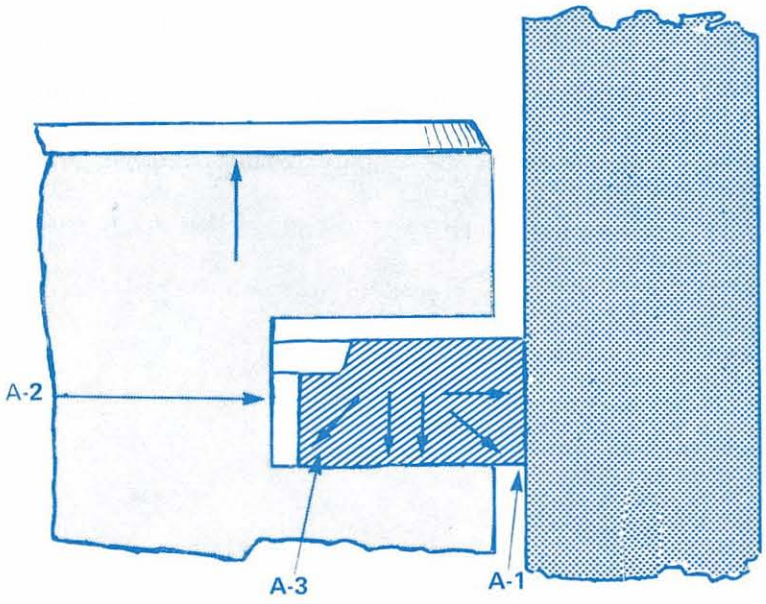


Figure 29

The oil ring in a 4-cycle engine must keep the oil in the crankcase from entering the combustion chamber. When a 4-cycle engine uses excessive oil it is because worn rings have allowed oil from the crankcase to enter the combustion chamber. The seal between the ring and the cylinder wall takes place at two points. Figure 29 shows the piston, ring and the cylinder wall. The seal takes place between the ring and the cylinder wall as shown at A-1 and the piston groove shown at A-2. The seal at the piston groove can be either at the top or the bottom, depending on which way the piston is traveling. Figure 29 shows the piston moving in the up direction on the compression stroke.

The ring is at the bottom of the groove in the piston as shown at A-3. When the piston begins the down stroke the seal is reversed as shown in Figure 30. The ring shown at A-1 is still against the cylinder wall as shown by the arrows but the ring is now pressing against the top of the ring groove as shown at A-2.

There is a top and bottom to most piston rings and you must install them right. If they are installed upside down the engine will use oil. If the grooves in the piston are worn badly the rings will not seat properly.

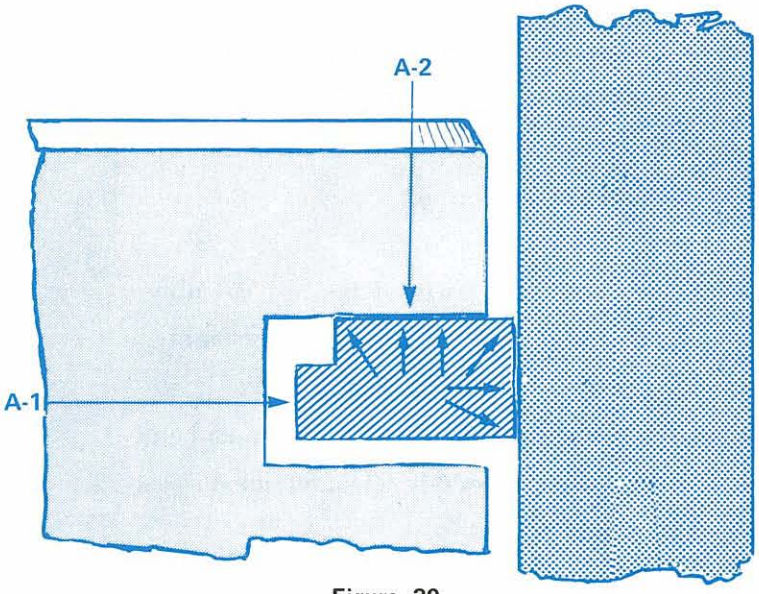


Figure 30

Figure 31 shows what happens if the groove in the piston has excessive wear. The ring will actually turn up at an angle as shown and allow a pressure leak at point A-1. This is known as blow-by. The rings will also have a tendency to chatter and break.

If rings are too tight they will overheat and score the cylinder wall. This is called freezing. Rings that are too loose will not seat and will very possibly break after a short time of operation.

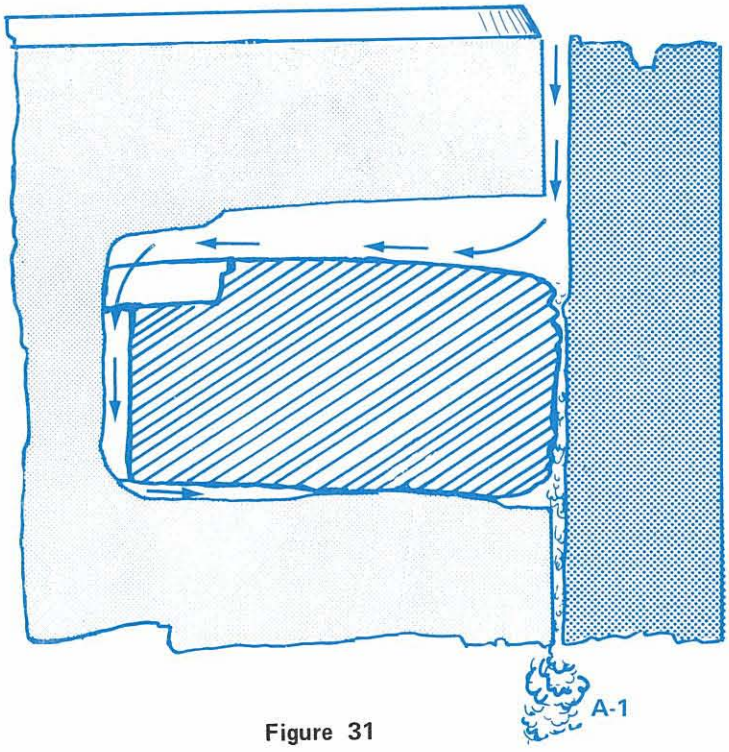


Figure 31

The clearance between the piston rings and the cylinder wall is very critical. Cylinders that are worn excessively may be rebored and fitted with oversize piston and rings. In order to rebore a cylinder for oversize rings and the piston, it is necessary to hone the inside of the cylinder walls.

Because of the very close tolerances between the piston, rings and cylinder wall, it is very important that all parts be kept clean when working in this area. A small amount of dirt in this area can cause the repair job to have a very short life.

ROD ASSEMBLY

The rod assembly is the part that connects the piston assembly to the crankshaft. The rod assembly converts reciprocating, or up-and-down motion, to rotating motion.

Figure 32 shows the parts of the rod assembly and their relationship to the piston assembly. The piston pin and the retaining rings are shown at A-1. They are contained in the piston and are part of the piston assembly. The retaining rings hold the pin in the piston.

The connecting rod shown at A-2 is connected to the piston pin. The other basic part of the rod assembly is the rod cap shown at A-3. The rod and the rod cap fit around the crankshaft and are held together with bolts and washers as shown.

Because of the construction of some rods and rod caps it is very important to install them properly. If you will examine the bottom of the rod and the top part of the rod cap you will generally find identification marks on one side or the other. When re-assembling these marks must be on the same side. They are known as matchmarks and they should always be checked before disconnecting the rod cap from the rod. Also, make a notation of which side of the engine these matchmarks are located so they can be installed exactly as they came out.

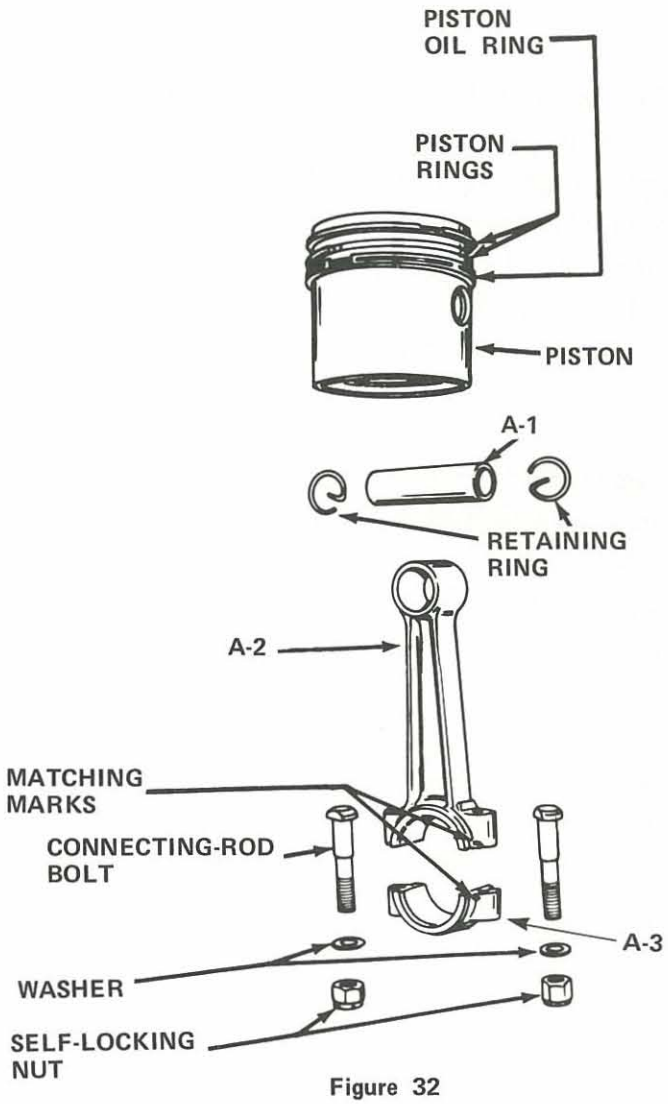


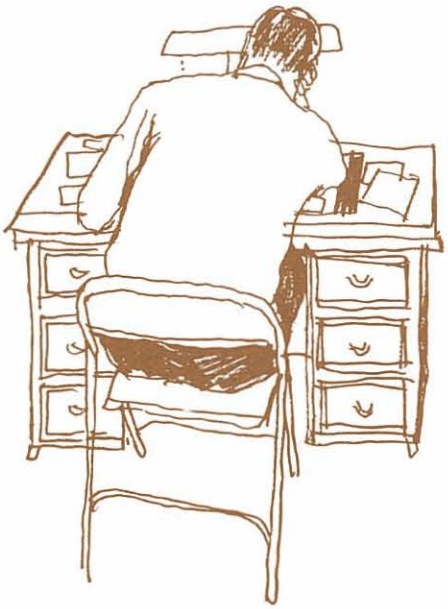
Figure 32

CHECKING FOR PROPER OPERATION

Improper operation of the cylinder and the piston and rod assembly are generally noticeable by poor compression, noisy operation and excessive oil consumption in 4-cycle engines. It is difficult to determine the exact cause of the trouble until you take the engine apart and inspect it. There are several things you can check before taking the engine apart that will give you an idea of the trouble. The compression check would generally be the first check as it will give you a good idea of the condition of the piston, rings and cylinder. Later we will cover the procedure for making a compression check. Excessive oil consumption would be indicated by puffs of blue smoke from the exhaust when the engine is running. This is usually due to cylinder wall or rings being worn. Frequent addition of oil would also indicate a bad cylinder or ring condition.

If the engine operates noisy it could be due to worn bearings either at the crankshaft or at the piston pin. Before attempting repairs on the piston, rod and ring assembly it would be best to check the crankshaft for scoring, and on 4-Cycle engines check the valves. If these parts are also worn it may be best to make the repairs by the "Short Block" method. Later we will go into more detail on the short block replacement. Basically it consists of the cylinder, piston, rod and ring assembly, crankcase, camshaft and valve already factory installed.

This short block replacement, completely factory assembled, will often cost less than purchasing the parts separately and the labor is kept to a minimum. There will be places where the short block method of repair is not possible or practical.



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. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
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1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
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4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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EXAMINATION ON LESSON 4
TWO AND FOUR CYCLE BASIC PRINCIPLES

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The four cycle engines requires the use of a reed vavle. ____
   TRUE
   FALSE

2. A four cycle engine produces a power stroke every second revolution of the crankshaft. ____
   TRUE
   FALSE

3. As the piston goes up and down, it turns the _____. ____
   a. crankshaft
   b. valves
   c. rings

4. The piston assembly consists of piston, rings, and wrist pin assembly. ____
   TRUE
   FALSE

5. The strokes necessary for a four cycle engine are intake, compression, power, and exhaust. ____
   TRUE
   FALSE

6. When a four cycle engine uses excessive oil, it is because worn rings have allowed oil from the gas to enter the combustion chamber. ____
   TRUE
   FALSE

7. The flywheel transmits power direct to the piece of equipment being operated. ____
   TRUE
   FALSE

8. The cams move the valves up and down in a two cycle engine. ____
   TRUE
   FALSE

9. Two cycle engines require two revolutions of the crankshaft for each power stroke. ____
   TRUE
   FALSE

10. On a four cycle engine, the crankshaft gear turns the gear on the camshaft. ____
    TRUE
    FALSE

(Continued on page 2)

11. The wrist pin connects the rod assembly to the piston. ____
    TRUE
    FALSE

12. In order for the camshaft gear to make one complete revolution, the crankshaft gear must make one revolution. ____
    TRUE
    FALSE

13. Oil control rings are generally used in the top ring groove. ____
    TRUE
    FALSE

14. _____ occurs when the fuel air mixture ignites too early. _____
    a. exhaust
    b. compression
    c. back fire

15. The fuel and oil mixture enters the top part of the engine on all two cycle engines. _____
    TRUE
    FALSE

16. The three types of rings generally used on a four cycle engine are compression, oil scraper, and oil control. _____
    TRUE
    FALSE

17. The two cycle engine requires the use of two valves. ____
    TRUE
    FALSE

18. The crankshaft gear is always larger than the camshaft gear. ____
    TRUE
    FALSE

19. The valve on a two cycle engine is located between the engine and the carburetor. _____
    TRUE
    FALSE

20. The oil control ring is always in the top groove of the piston. ____
    TRUE
    FALSE

21. The oil control ring in a TWO CYCLE ENGINE keeps the crankcase oil from entering the combustion chamber. _____
    TRUE
    FALSE

22. The four cycle engine requires a separate system of lubrication. ____
    TRUE
    FALSE

23. Mark the following statements as true or false, as they pertain to the four cycle engine illustrated in Fig. 4-1.
    a. camshaft gear
    b. crankshaft gear
    c. valves
    d. piston
    e. rod assembly
    f. crankshaft
    g. cam
    h. flywheel

24. Mark as true or false the following statements as they pertain to the piston shown in Fig. 4-2.
    a. ring groove
    b. head
    c. wrist pin
    d. skirt

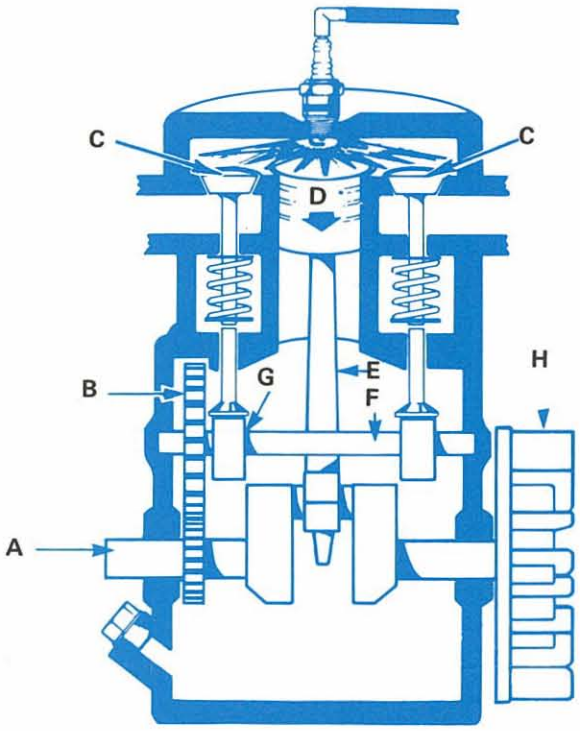

Figure 4-1

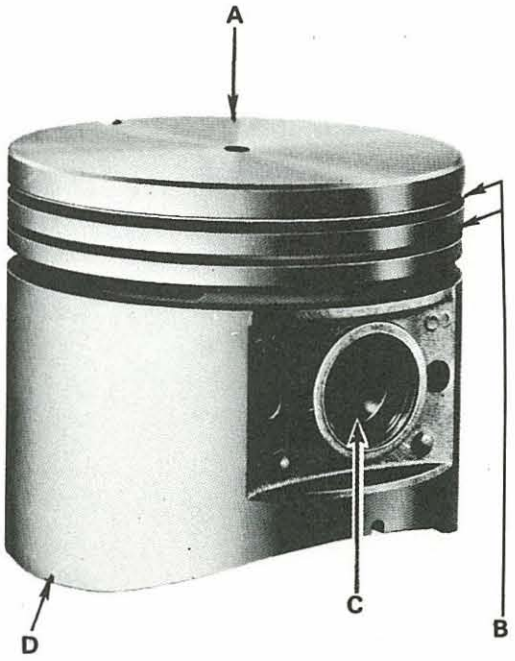

Figure 4-2

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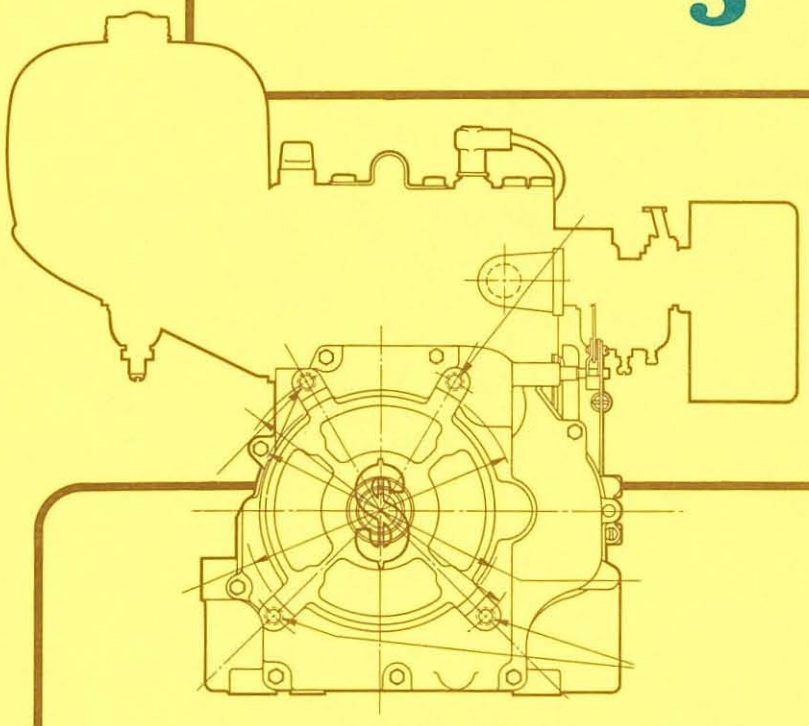

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2-CYCLE AND 4-CYCLE SIMILARITIES

So far we have been concerned with the basic engine principles as they apply to both 2 and 4 cycle engines. Identification, care and maintenance, cooling, basic operation and the piston and cylinder assembly all have much in common with both the 2 and 4-cycle engine.

Later we'll go into more detail of the exact functions and how the fuel and air mixture is converted into mechanical energy or work. The ignition spark ignites the fuel and air mixture and causes an explosion that makes the engine operate. Carburetion, or delivering the fuel and air mixture to the proper place until combustion takes place involves all phases from the fuel tank on through the carburetor.

FUEL SYSTEM

The fuel system is basically divided into four sections. First we have the storage of the fuel which is normally the fuel tank attached to the engine. Next we have the delivery of the fuel to the carburetor. This can be either by a gravity feed system with the storage tank located higher than the carburetor or it can be force fed by the use of a fuel pump. We know that one of the functions of the carburetor is to mix air with the fuel. Since this mixture goes into the engine it is very important that the mixture be clean and free of foreign matter that would damage the engine. This brings us to the third part of the fuel system. The filter or cleaner is one of the most important parts of the fuel system and one that is often overlooked. The fourth part of the fuel system is the carburetor itself.

CLEANERS

There are three basic types of air cleaners used on most all types of small engines. Most small engine mechanics will have a preference of one over the other but they will all three do a satisfactory job if serviced properly. Air cleaners are not all serviced the same way so it is important that you be able to identify the air cleaner you are working on and service it properly. The wrong service procedure on an air cleaner can have the same effect as no service at all. Another part of the filter system which we'll cover later is the different types of fuel strainers. Foreign matter can enter both through the air system and the fuel system, so they both must be kept clean at all times.

OIL BATH AIR CLEANERS

An oil bath air cleaner actually washes dirt and foreign matter from the air by forcing the air through a bath of oil. Figure 33 shows a typical oil bath filter. Air enters the cleaner under the edge of the cover as shown at A-1. Air is allowed to enter all around the top of this filter and flows through the space between the body shown at A-2 and the outside shell shown at A-3. The cause of this air flow is due to a pressure differential caused by the downward stroke of the piston. This actually causes a suction of air to the carburetor.

As air enters the cleaner under the outside edge, it is directed down to the oil supply shown at A-4. When the incoming air strikes the oil pool it deposits some of the foreign matter or dirt. Dirt is trapped in the oil and filters to the bottom. When air reaches this point its path is directed in the opposite direction as shown at A-5. Oil is picked up and carried along with the air. Dirt particles are coated with oil as they begin to pass through the filter as shown at A-6. This filter usually consists of long strips of crimped metal or small wire mesh. This requires the air to move around through this mixture and deposit the oil-coated dirt. As more dirt and oil collect in the filter it drains back into the oil chamber shown at A-4. The dirt then settles to the bottom and the oil is reused. This can only go on so long and then the oil will become over-saturated with dirt.

When the air reaches point A-7 it should be free of foreign particles if the filter system is serviced properly. It is then ready to enter the carburetor as shown at A-8. This filter is known as the oil bath filter because oil is actually picked up by the air in a fine mist and then deposited in the filtering element along with the oil-coated dust particles. Excess oil and dirt then drain back into the oil chamber.

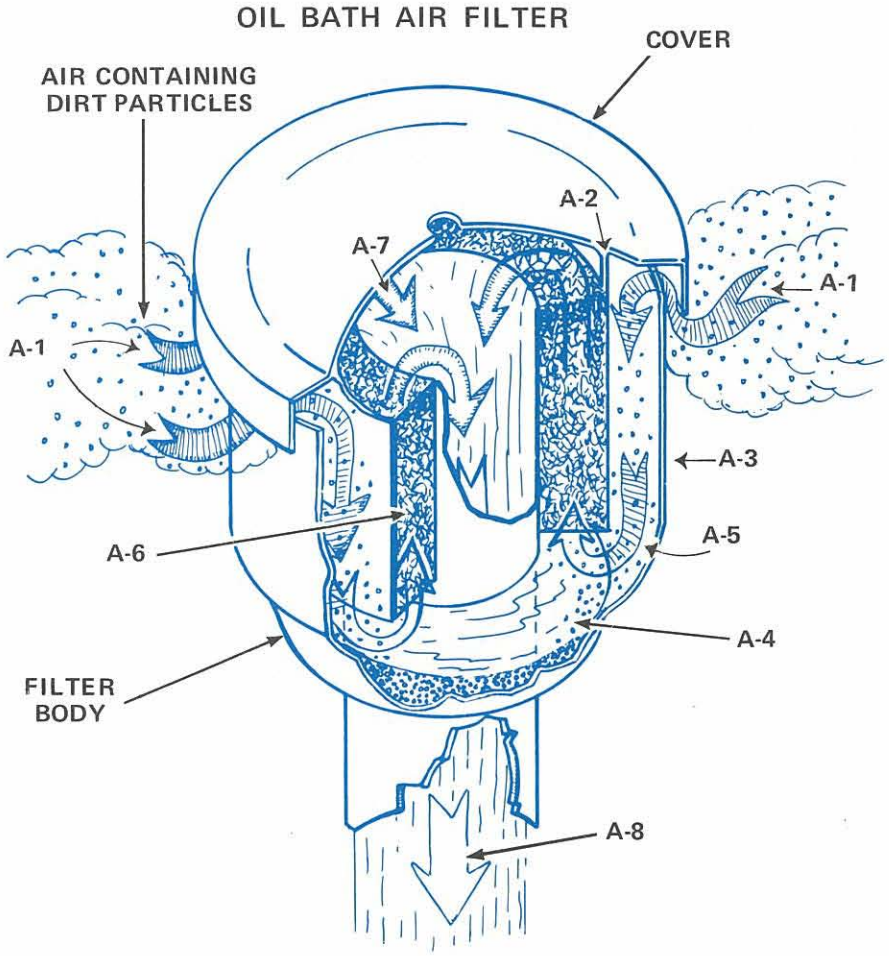


Figure 33

OILED FILTERS

The filter shown in Figure 34 is known as an oiled filter cleaner. The unfiltered air enters at point A-1 and passes through a filtering material generally made of aluminum foil mesh or fine wire matted together. This filtering material is coated with oil before it is installed and after each cleaning. It is designed so air passes over a large area of the oiled surface. Oil on the filter material picks up dirt and dust and prevents them from going into the carburetor. It is very important that the filter material be oiled. Since this material does not appear to be an absorbent it is often thought of as a dry filter. Unless it is oiled, this filter will do very little because dirt will pass right through it. Oil acts like a magnet in attracting dirt and dust, and without oil foreign matter will pass easily through this filter.

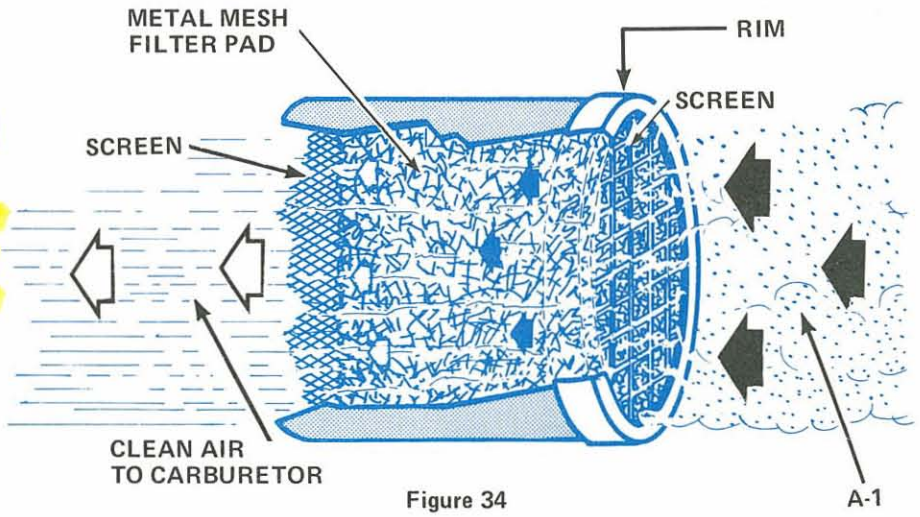
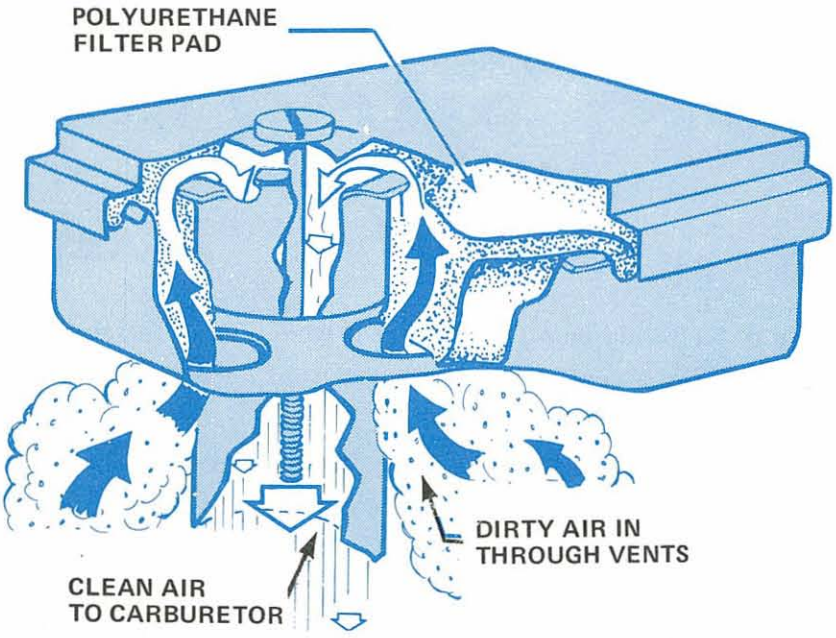


Figure 34

OILED-FILTER AIR CLEANER



Another type of oiled filter that is very commonly used is shown in Figure 35. This filter operates in the same manner as the filter using foil except it uses a polyurethane pad. This filter is easily cleaned by rinsing it in a solvent.

Figure 35

DRY FILTERS

The dry air filter, as the name implies, uses no oil to help trap dust and dirt. It depends on incoming air being forced through a porous filtering element. This type filter is usually made of paper, moss, or hair. These filters have very small openings that keep all except extremely small particles from passing through. They are considered replaceable and generally are not cleaned. Figure 36 shows a typical dry filter. Incoming air enters at point A-1 and is forced through the filter paper at A-2. Small holes in the paper allow air to pass through but trap the fine particles of dust and dirt. After the air is filtered it is sucked to the carburetor as shown at A-3.

DRY-FILTER AIR CLEANER

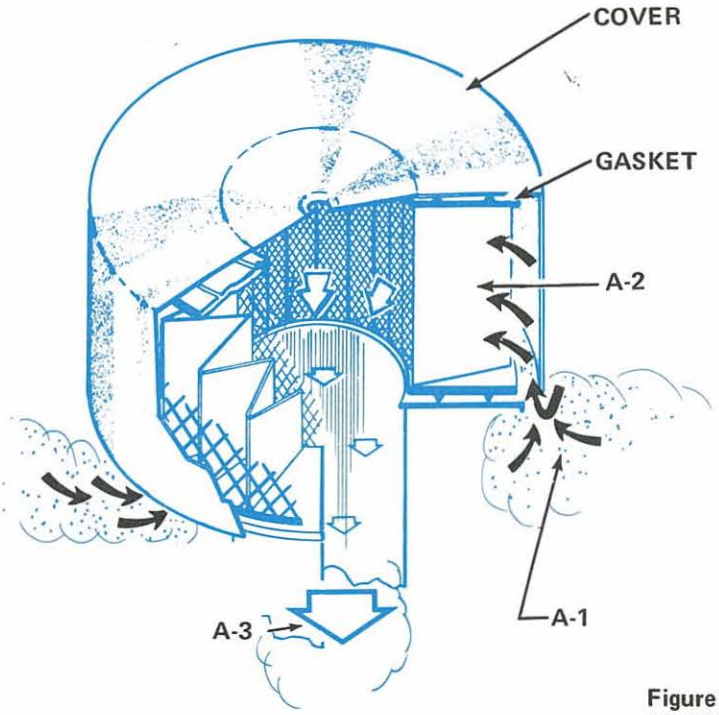


Figure 36

IMPORTANCE OF AIR CLEANER SERVICE

The air cleaner, or filter, is probably one of the biggest causes of engine trouble or failure. One of the reasons is that it is not considered as an important part of the engine, when actually it is one of the most important functions of any engine because it controls the amount of air entering the carburetor and the engine. Fuel is not combustible without air. A 3-horsepower engine will use over six cubic feet of air for every minute it is operating. It requires this much air to provide the best combustible fuel and air mixture for efficient operation. This quantity of air would be no problem if it were not for the air filter restricting the amount of air entering the carburetor, but air entering the carburetor must be clean.

Since most small engines operate near ground and in dusty places, much thought and engineering has gone into the design of air cleaners used on small engines. The efficiency of air cleaners used on these engines is limited, not by the design of the filter but by its care and maintenance.

Failure to service the air cleaner properly will allow dirt and dust to pass into the engine and mix with the lubricating oil or it will build up on the air cleaner filter. When foreign matter builds up in the air cleaner filter it will choke the engine and cause an excessively rich mixture of fuel and air. This will shorten the life of the engine.

If dirt gets past the air cleaner it will enter the combustion chamber and mix with the oil that lubricates the moving parts. When this happens the oil is no longer a lubricant but acts like a grinding compound.

If too much foreign matter is allowed to accumulate in the filter, it reduces the amount of air necessary for adequate combustion and allows too much fuel to enter the combustion chamber. When this happens all the fuel does not burn and the unburned gas will wash the lubricating oil from the cylinders. Fuel will also enter the crankcase and dilute the lubricating oil.

AIR CLEANER SERVICE SCHEDULES

There is no set schedule for cleaning air cleaner filters as this will vary with the conditions the engine is operating under. Under ideal conditions, free of dust and dirt, fifteen to twenty hours of operation would be a good schedule for cleaning. If the engine is operated in extremely dusty conditions it may be necessary to clean the filter every two or three hours. Since operating conditions will indicate how often the cleaner needs servicing customers should always be aware of the necessity of frequent cleaning. Most of these filters can be cleaned in a matter of minutes and, by doing so, will add many hours of life to the engine. The engine on a lawnmower may require cleaning only once every second or third time it is used, while a chain saw may require cleaning the filter several times each day.

SERVICING AIR CLEANERS

Never remove the air cleaner from the engine when it is running. This allows any foreign matter direct access to the carburetor and the engine. There is also danger of getting hurt when working on an engine that is running. The only service functions you should attempt while the engine is running are those related to the final adjustment such as the high and low speed carburetor jets which we will cover later. Always remove the spark plug wire when working on an engine.

SERVICING FUEL STRAINERS

Dirt and foreign matter can enter either the carburetor through the air filter or directly through the fuel lines. Gasoline and other fuels always have a certain amount of foreign matter in them that will cause trouble if allowed to enter the carburetor. There are three basic types of fuel strainers used on most engines.

FUEL-FILTER
(GLASS SEDIMENT BOWL AND SCREEN)

Figure 37 shows the glass sediment bowl-type filter. Fuel comes direct from the tank as shown at A-1. There is a shut-off valve shown at A-2. This shut-off valve should be closed when the engine is not operating or is in storage. This filter is one of the most efficient filters made but is not too common on many engines.

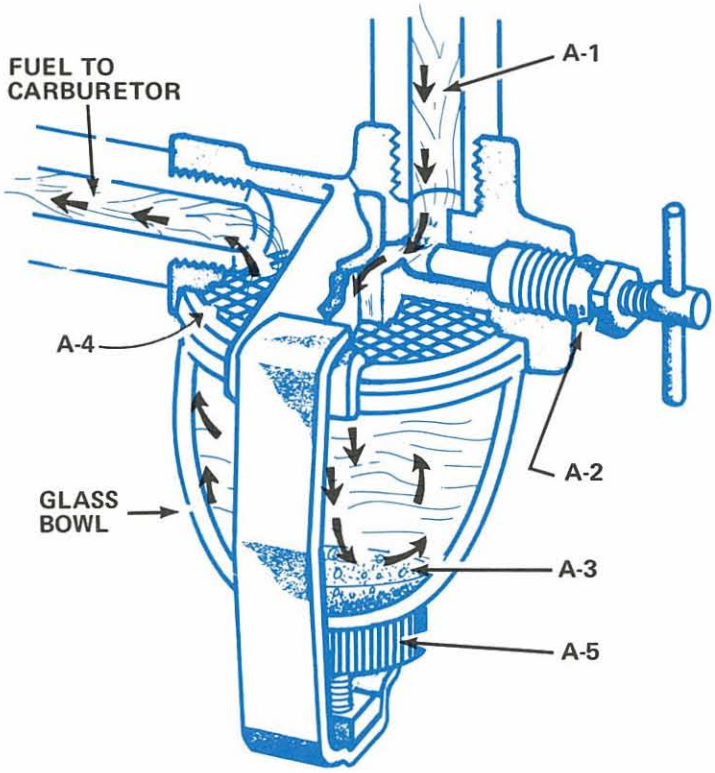


Figure 37

Since this strainer depends on gravity for operation it can only be used on engines operating in an upright position. It is not used on chain saws or other engines operated in multi-purpose work positions. They are used more on larger stationary engines operating in an upright position.

The purpose of the glass bowl is to allow dirt and water to settle to the bottom. Since both water and dirt are heavier than gasoline they will settle to the bottom of the bowl as shown at A-3. Before the fuel passes from the tank to the carburetor it goes through the filter screen shown at A-4. Water and solids then settle to the bottom and gas goes directly to the carburetor either by gravity feed or force feed through a fuel pump. The nut shown at A-5 can be loosened for removal of the glass bowl for cleaning.

The screen in tank filter shown in Figure 38 is very popular in many small engines. It is attached directly to the shut-off valve. This strainer is cleaned by removing the nut shown at A-1 and then removing the shut-off valve shown at A-2. Air is then blown in through the bottom of the tank to clean the strainer shown at A-3. The tank must then be washed out and turned upside down to remove all foreign matter.

FUEL FILTER
(SCREEN IN TANK)

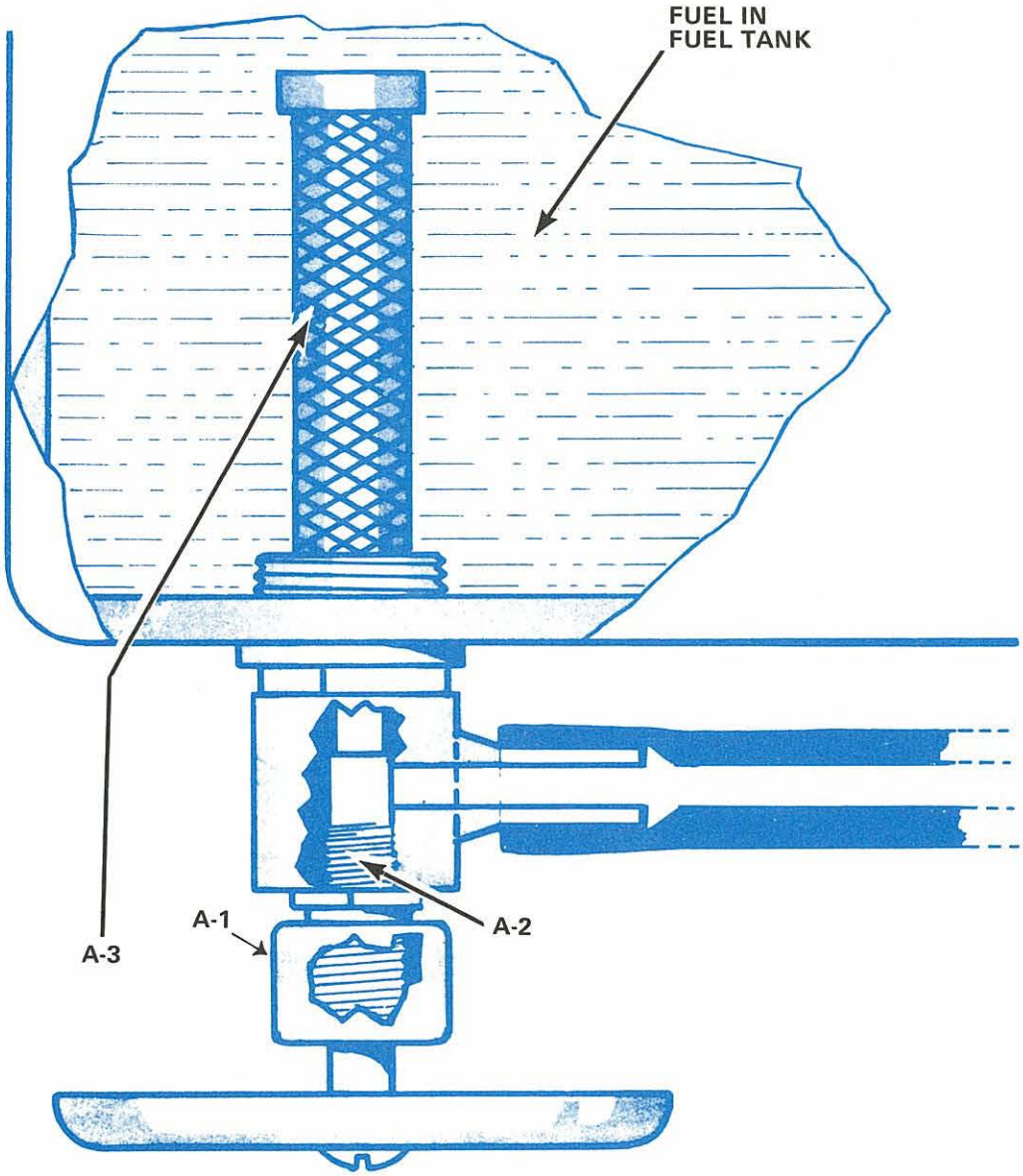


Figure 38

You can see how engines operating in any position such as chain saws would have trouble with this type of fuel filter and drain line from the gas tank. If the tank were low on fuel and the engine were tilted to one side, no fuel would leave the tank. This is overcome by the use of a special strainer design as shown in Figure 39. The strainers are the same design except this one is attached to the end of a flexible hose that has a weight on the end to keep the strainer at the bottom of the tank, regardless of the position of the engine. The strainer will always be at the lowest point in the tank and in the fuel supply. In addition to fuel strainers the gas tank will sometimes have an additional strainer at the top where it is filled. All fuel passing into the tank will be filtered for fine particles of foreign matter before it enters the tank.

If fuel strainers are not kept clean they will clog up with foreign matter and not allow an adequate supply of fuel to enter the carburetor. This will starve the engine of fuel and cause it to run rough and often not run at all. Any engine cannot operate efficiently with dirt or foreign matter in the gasoline, since the fuel is metered or fed to the carburetor through a very small needle valve and jets. These regulate the amount of gas and air going to the carburetor and can very easily be clogged with foreign matter.

FUEL FILTER
(STRAINER ON FUEL PICK-UP HOSE)

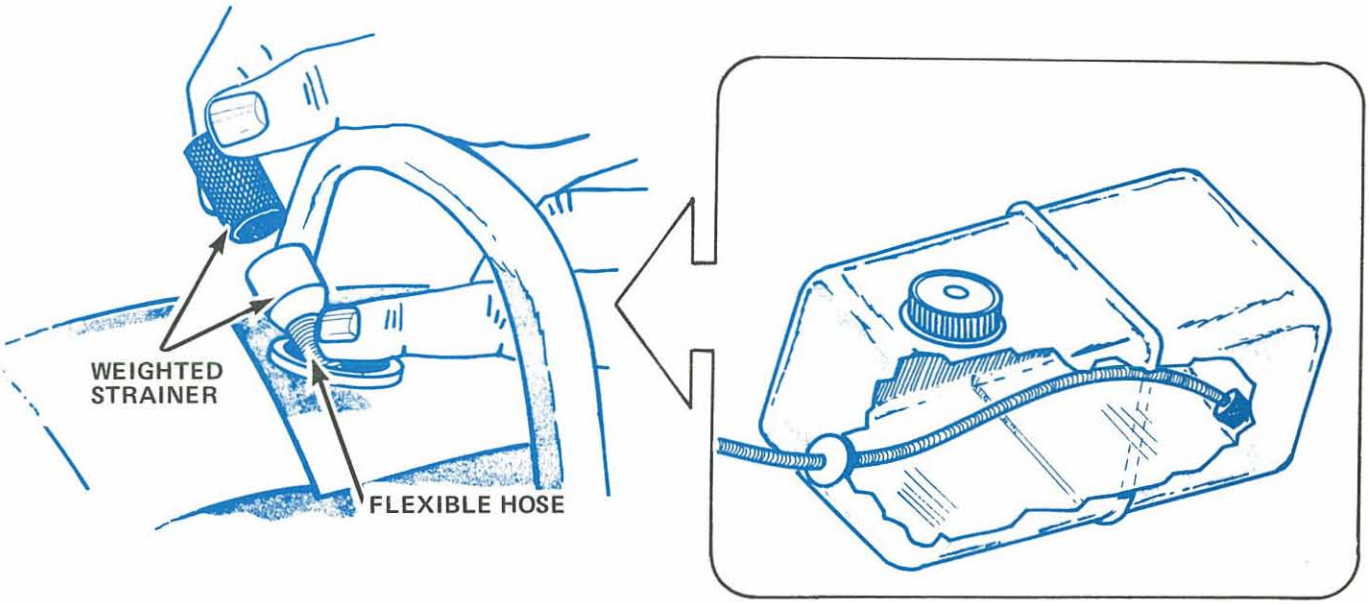
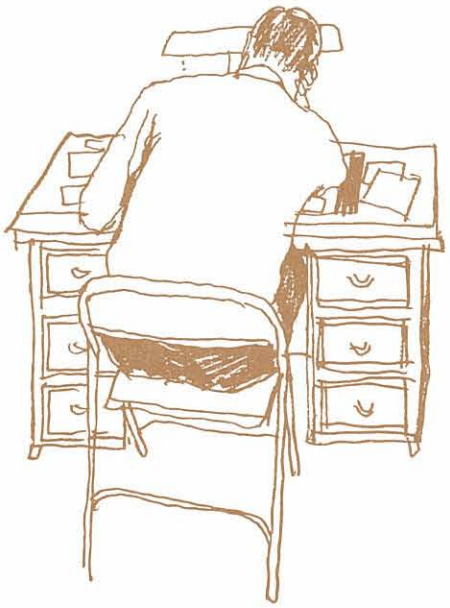


Figure 39



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

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LESSON NO.(S) _____ . _____ (FILL IN)

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STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
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(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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EXAMINATION ON LESSON 5
AIR CLEANERS AND FILTERS

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(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. A clogged air filter can restrict the amount of air entering the carburetor. ___
   TRUE
   FALSE

2. The three basic types of fuel strainers are the sediment bowl, screen in tank, and strainer on the end of the fuel pickup hose. ___
   TRUE
   FALSE

3. _____ filters forces air through a filtering material generally made of foiled mash, fine wire, or polyurethane pad. ___
   a. oil bath
   b. oiled
   c. dry

4. It is always best to service an air filter while the engine is running. ___
   TRUE
   FALSE

5. _____ filters depend on incoming air being forced through a porous filter element. ___
   a. oil bath
   b. oiled
   c. dry

6. If the nameplate gives specifications for mixing oil and fuel, it is a four cycle engine. ___
   TRUE
   FALSE

7. The fuel storage tank, the fuel delivery, the fuel filter, and the carburetor comprise the four basic parts of the fuel system. ___
   TRUE
   FALSE

8. A fuel and oil mixture is used on all two cycle engines. ___
   TRUE
   FALSE

9. Oiled air filters wash dirt and foreign matter from the air by forcing it through a mixture of oil. ___
   TRUE
   FALSE

(Continued on page 2)

10. Under ideal operating conditions, air filters should be cleaned or replaced every _____ of operation. _____
    a. 10 to 25 hours
    b. 15 to 20 hours
    c. 20 to 25 hours

11. Since gasoline is heavier than water or dirt, foreign matter will float on top. _____
    TRUE
    FALSE

12. The three basic types of air filters used on small engines are the oil bath, oiled, and dry. _____
    TRUE
    FALSE

13. When foreign matter builds up in the air filter, it causes a lean mixture of fuel. _____
    TRUE
    FALSE

14. Mark the following parts or functions of the air filter as shown in Fig. 5-1.
    _____ air entry
    _____ oil supply
    _____ filter element
    _____ air
    _____ clean air

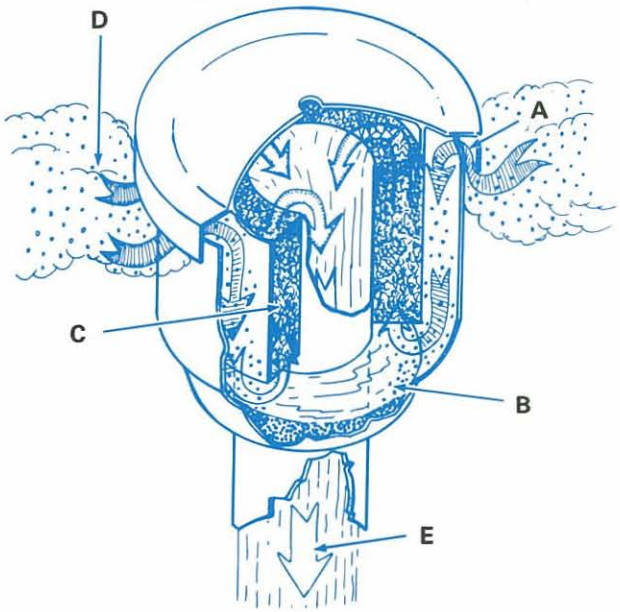

Figure 5-1

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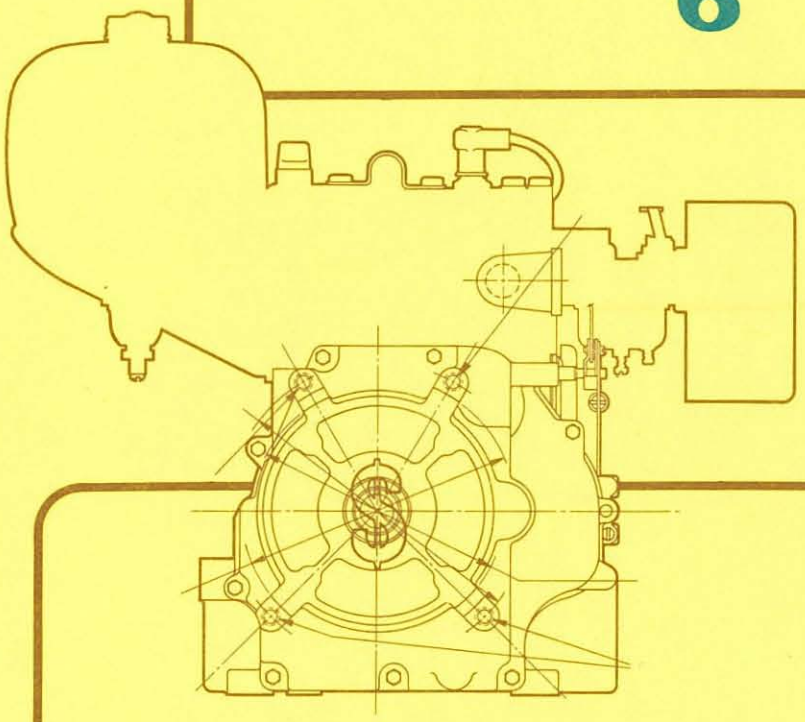

TURN THIS PAGE

...and let's find out all about -- **CARBURETION**

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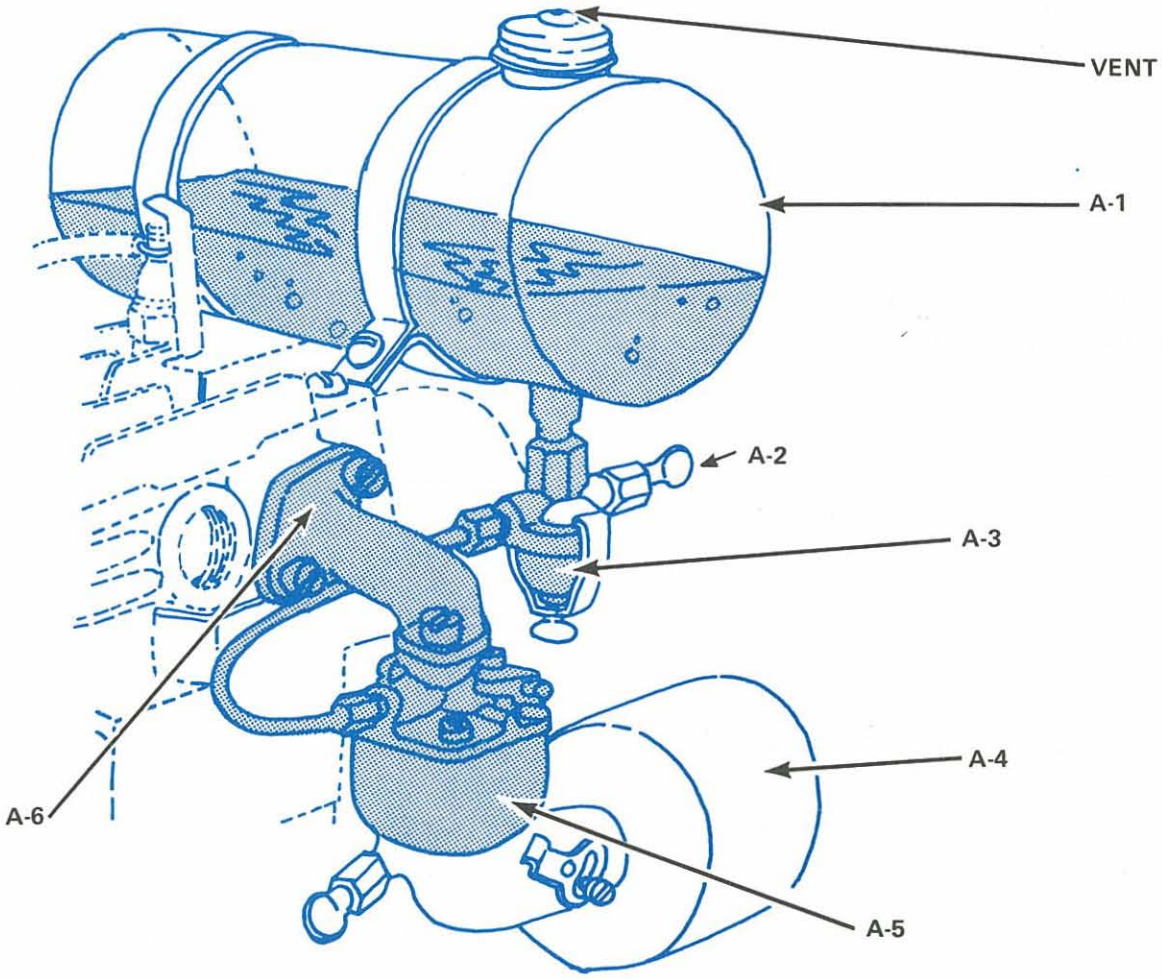
BASIC FUEL SYSTEM

The fuel system includes everything necessary to get fuel from the fuel tank into the engine. It also combines the raw fuel with the proper amount of air necessary to form the combustible mixture. A typical basic fuel system is shown in Figure 40. This is a gravity feed type system with the fuel tank above as shown at A-1. There is a shut-off valve shown at A-2 that can be used to cut off all fuel from the fuel system and the engine. This valve is normally closed when the engine is not in operation.

The strainer is shown at A-3. The air filter shown at A-4 keeps dirt from entering the carburetor with the air. The float bowl shown at A-5 is the reservoir of fuel for metering to the carburetor. The fuel is then mixed with air and goes into the engine at A-6. This is the basic principle of the fuel system. There are several variations of the way the fuel and air actually are mixed and fed into the engine. We'll cover each of these individually.

Figure 40

GRAVITY-FEED FUEL SYSTEM



CARBURETOR FUNCTIONS

The function of the carburetor on a spark-ignited engine is to atomize the fuel or reduce it to a spray form. It then mixes the atomized fuel in the proper proportions with the air flow to the engine. Different fuel air mixtures are required to meet the varying demands of the engine.

CARBURETION

In a completely filled and closed container without air, gasoline will not burn. Oxygen must be present to make combustion possible. Gasoline is a very volatile substance. It evaporates quickly and mixes with air. Oxygen is the basic component of air and is needed to make gasoline burn. When gasoline is combined with air it forms a vapor and becomes highly inflammable. When this mixture of gasoline and air is exposed to a spark it is very explosive. In order for an internal combustion engine to develop all the possible power available the explosions must be sudden and complete. All the fuel must be burned in the shortest possible time.

If the mixture has too much air it is referred to as too lean and will cause slow combustion. If the mixture is too rich or has too much gasoline for the amount of air it will have incomplete combustion and will reduce the power output of the engine. To obtain the sharpest and strongest explosion the fuel and air mixture must be correctly proportioned and mixed. The carburetor is just a metering device used to mix the proper amount of air and fuel to get the maximum possible results.

FUEL-AIR MIXTURE RATIO

To meet the demands of an engine being operated at varying speeds and loads, the carburetor must mix fuel and air at different ratios. Fuel-air ratios for different operating conditions have the following relationship:

	Fuel		Air
Starting, cold weather	1	to	7
Accelerating	1	to	9
Idling, (no load)	1	to	11
Part open throttle	1	to	15
Full load, open throttle	1	to	13

Since engines are designed and used in many varying applications requiring different loads and speeds the air mixture combined with the fuel can be varied to meet the applications the engine is being used for.

FUEL TANK VENTING

Fuel tanks must be vented to prevent a vacuum from forming in the tank and stopping the flow of fuel. Tank caps have a vent hole as shown in Figure 40. This hole generally is in the center and permits air to enter the tank. Sometimes this hole will have a screw adjustment so it can be closed to keep the tank air-tight when not in use.

A closed vent can be a very common source of trouble as it will create a vacuum in the tank as fuel is being used. The engine will run for a short time and stop. Generally, in a few minutes, the vacuum will decrease and the engine can be started again but only for a short time. If this vent hole is clogged with foreign matter the engine will not operate properly. It should be kept clean at all times.

CARBURETOR PRINCIPLES

There are three basic types of carburetors used on most all small gas engines, but first let's see how carburetion works. A carburetor has three functions. It regulates the ratio of fuel and air mixture necessary to get maximum combustion. Second, it breaks up or atomizes the fuel into a fine spray or mist and mixes it with air. Third, it regulates the amount of fuel and air mixture going into the combustion chamber.

The fuel air ratio is controlled by adjusting needle valves and can be adjusted to meet the required conditions of the engine. As the engine is used these can become out of adjustment allowing either too much air or too rich of a fuel mixture.

Figure 41 shows the 2-cycle carburetor operating principle. Anytime a piston moves up or down in a cylinder it tends to produce a partial vacuum or compression.

Point A-1 shows the piston moving up in the cylinder. This creates a low pressure area or partial vacuum in the crankcase and lifts the reed valve shown at A-2. Atmospheric pressure, which is the pressure of the air around us, is high at point A-3. This high pressure pushes the air into the carburetor intake to equalize the low pressure area.

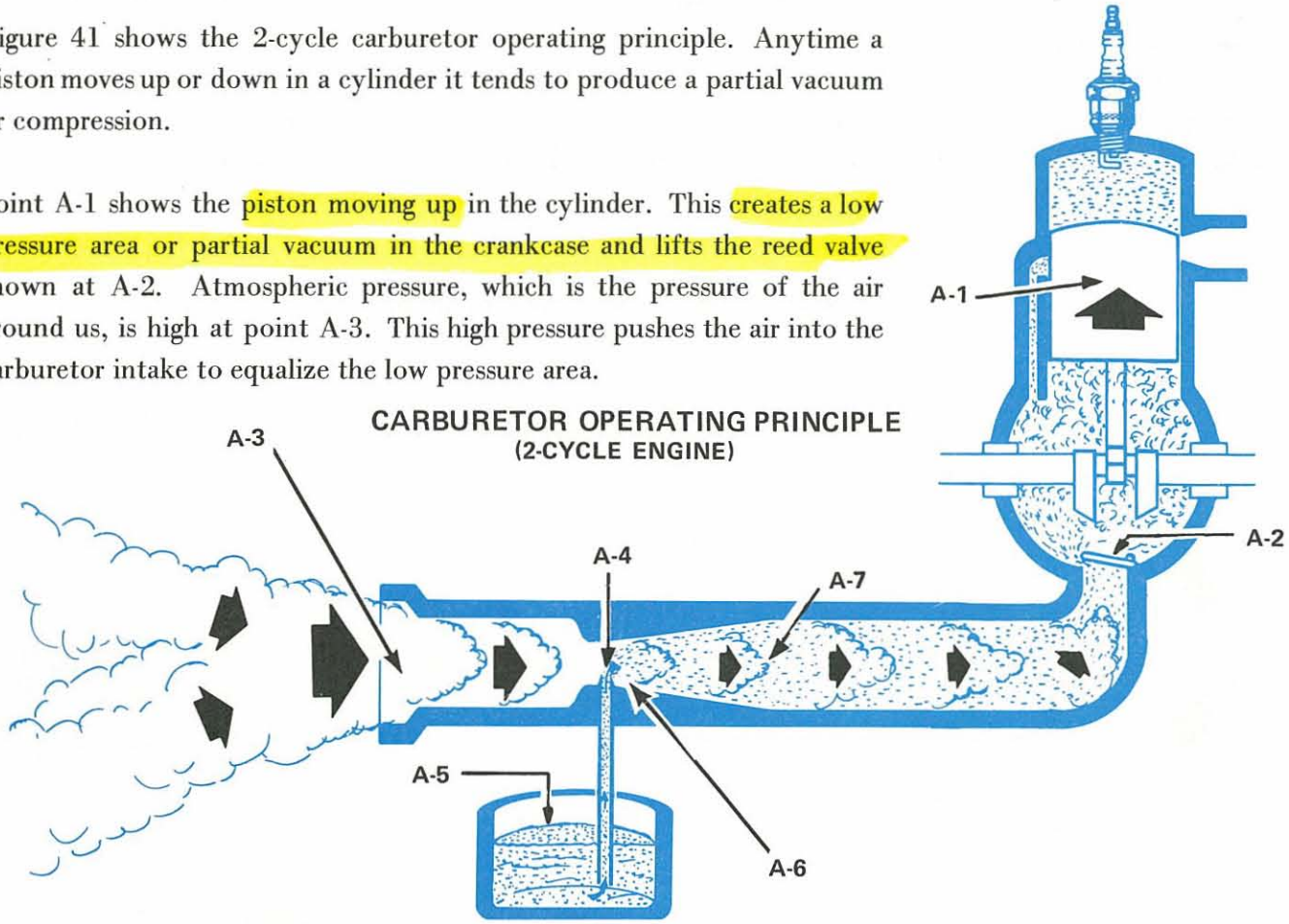


Figure 41

TYPES OF CARBURETORS

The Float carburetor, Diaphragm carburetor and Suction Lift carburetor are three basic types of carburetors used on small engines. Each of these operate on a different principle and we'll cover each of them individually. The configuration of the external parts will vary in appearance but each operates on the same basic principle. There are about eight different manufacturers of small engine carburetors but they will all fall into these three general categories. You'll run into such names as Walbro, Carter, Tillotson, Brown, Clinton, Zenith, Marvel-Schebler and the one used on Lawn Boy engines which is made by the engine manufacturer.

THE VENTURI

A Venturi is nothing more than a restriction inside a passage way. The opening is larger on both sides and smaller, or restricted, in the center as shown at A-4 in Figure 41. Air speed increases in the venturi because of the narrower passage. As the same volume of air or liquid is forced through an opening the pressure increases as the opening becomes smaller. As the opening becomes larger the pressure decreases. Air speed increases as its pressure is lowered. When the pressure in the venturi is lowered, atmospheric pressure at A-5 in the fuel bowl forces the fuel up through the pipe, as shown at A-6, and into the area of the venturi and into the air stream. The speed of the air in the venturi causes a turbulence in the area of A-7. When this turbulence develops it causes the fuel to break up into tiny drops and mix with the air forming a vapor. This is a mixture of fuel and air like a fine mist or stream.

The carburetion principles of the 4-cycle engine are the same as for the 2-cycle except the partial vacuum or low pressure area is created by the downward stroke of the piston as shown in Figure 42.

CARBURETOR OPERATING PRINCIPLE
(4-CYCLE ENGINES)

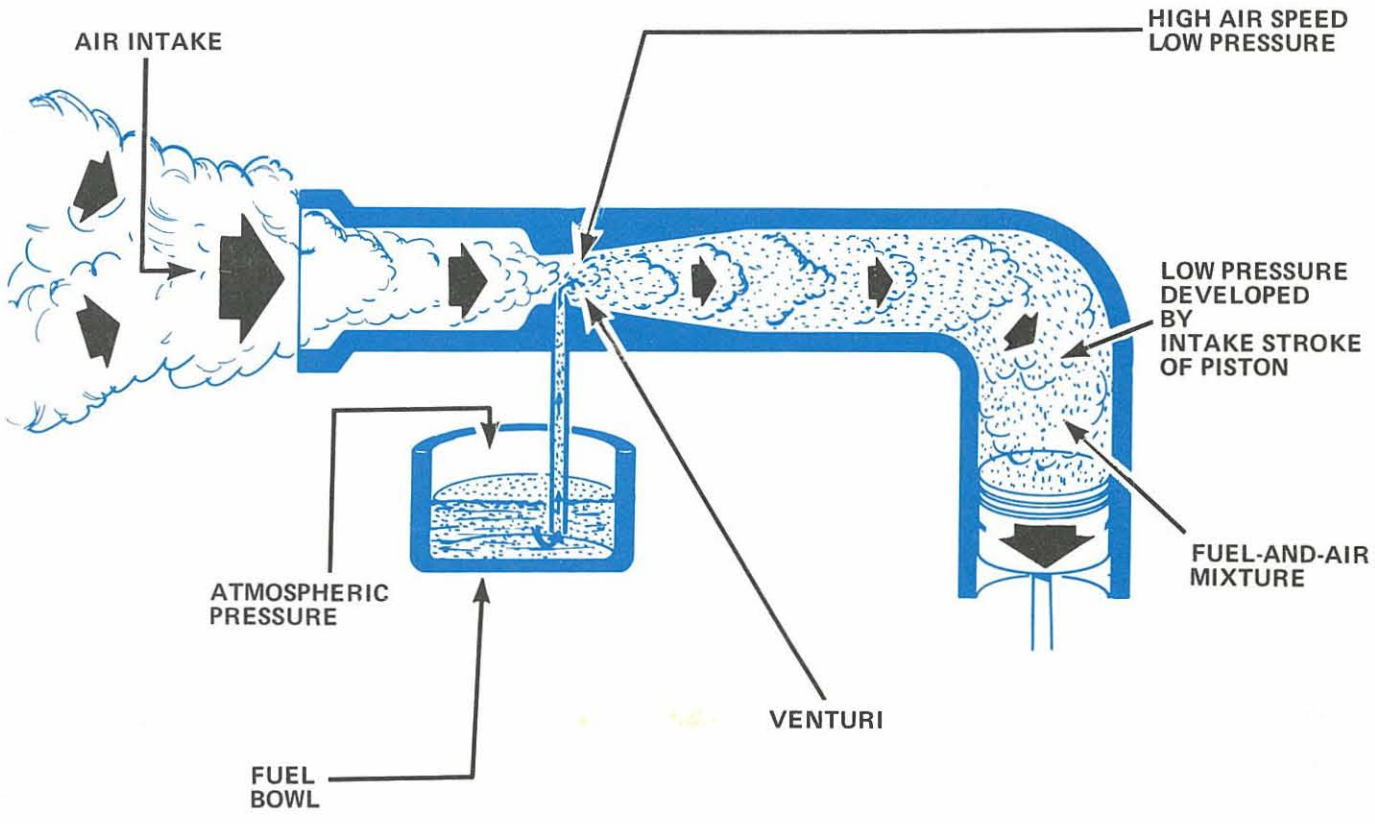


Figure 42

CARBURETOR THROTTLE VALVE

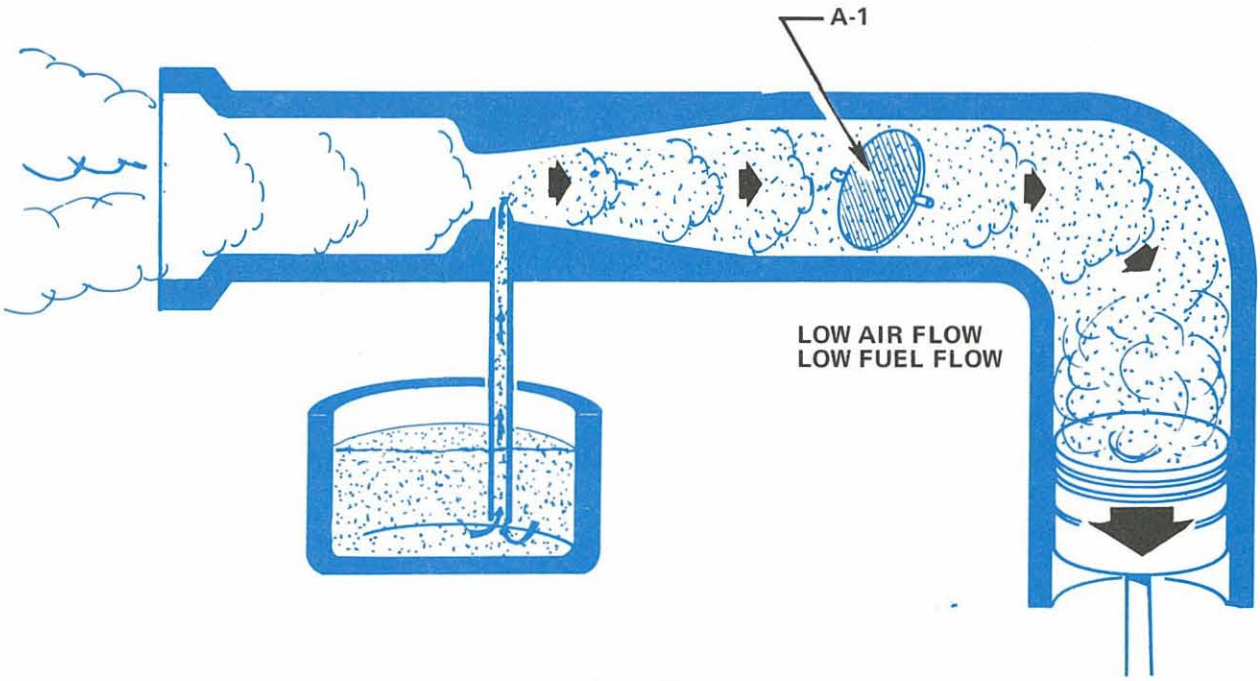


Figure 43

THROTTLE VALVE

After the air and fuel are mixed it is necessary to provide a method of controlling the amount of fuel and air mixture going into the carburetor. This has to be variable since the engine will require different amounts when operated at different speeds. The principle of the throttle valve and the choke valve are the same for both 2-cycle and 4-cycle engines.

Figure 43 shows the throttle valve installed in the carburetor system. This valve controls the amount of fuel and air going to the combustion chamber of the engine. The throttle valve is shown at A-1. If you open this valve the engine will run fast. As the valve is closed the engine will run slower. The more fuel and air going to the engine, the faster it will run.

The throttle valve does not change the mixture of the fuel and air. This valve just regulates the amount of fuel and air allowed to enter the combustion chamber.

CHOKE VALVE

Next, we'll add the Choke valve. This valve is used to decrease the amount of air in the mixture when starting a cold engine. Figure 44 shows the location of the Choke valve at A-1. This is on the air intake side of the carburetor next to the air filter. The choke valve at A-1 is in the partially closed position and restricts the amount of air that is being mixed with the fuel. The throttle valve shown at A-2 is open, allowing a very rich mixture of fuel to enter the engine. This mixture has a lot of fuel and very little air. It has just enough air to make it combustible. Only vaporized gasoline is combustible. Without air it will not burn. The richer mixture caused from the choke valve being almost closed provides for more gasoline to be vaporized.

CARBURETOR CHOKE AND THROTTLE VALVE

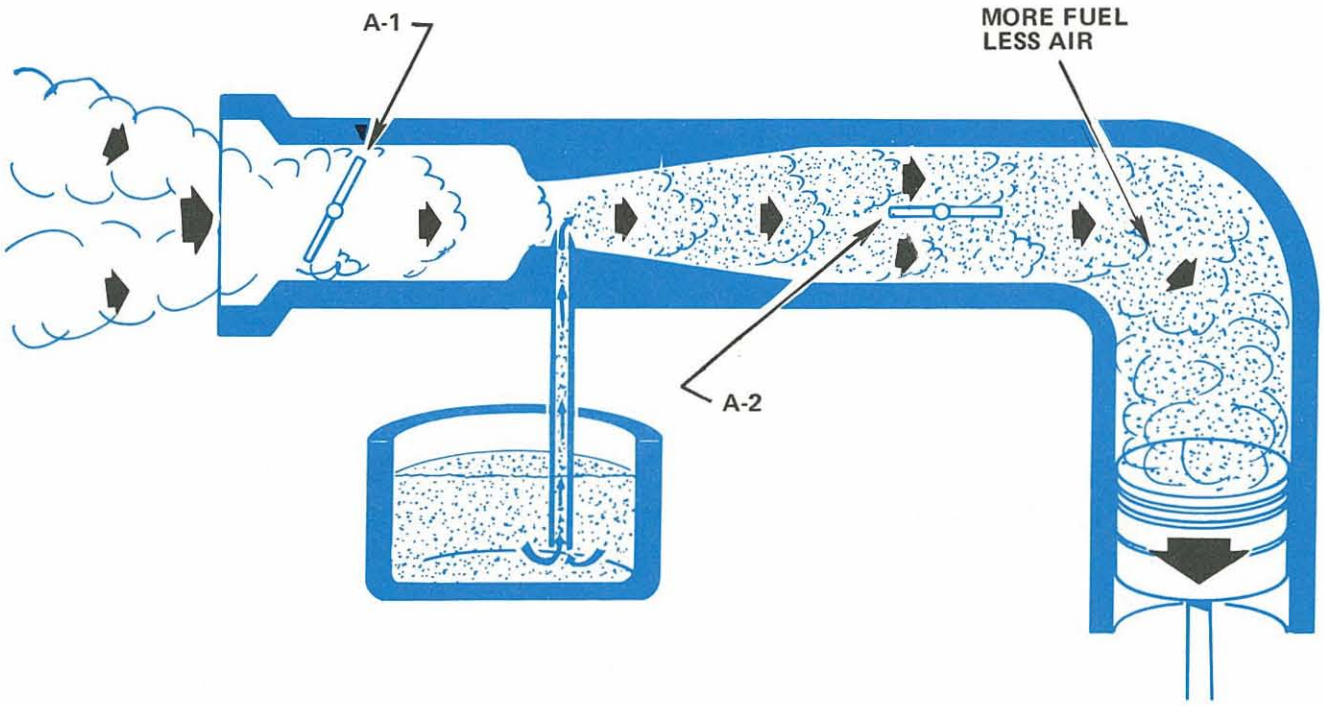


Figure 44

The design of the choke valve is almost the same as the throttle valve but its function is different. The throttle valve controls the amount or volume of fuel-air mixture going to the engine and the choke valve only controls the amount of air that is to be mixed with the fuel.

If an engine were to be operated at one constant speed with one constant load and no variations, these basic principles of carburetion would be adequate to operate the engine providing it were set with controlled temperature, air and altitude. These conditions are so variable that it is necessary to add other components to the carburetor to compensate for operational conditions.

When an engine is operating, different air and fuel mixtures are necessary to meet different loads and speeds. Figure 45 shows the two basic adjustments necessary to make the carburetor supply the engine with the proper amount of fuel and air mixture. The fuel supply in the carburetor bowl is shown at A-1. We have already covered how the air pressure differential caused by the air passing through the venturi sucks the fuel up through the tube shown at A-2 and mixes with the incoming air. Notice the fuel can go either straight up to point A-4 or it can go to the idle mixture adjustment valve at A-5.

CARBURETOR ADJUSTING VALVES

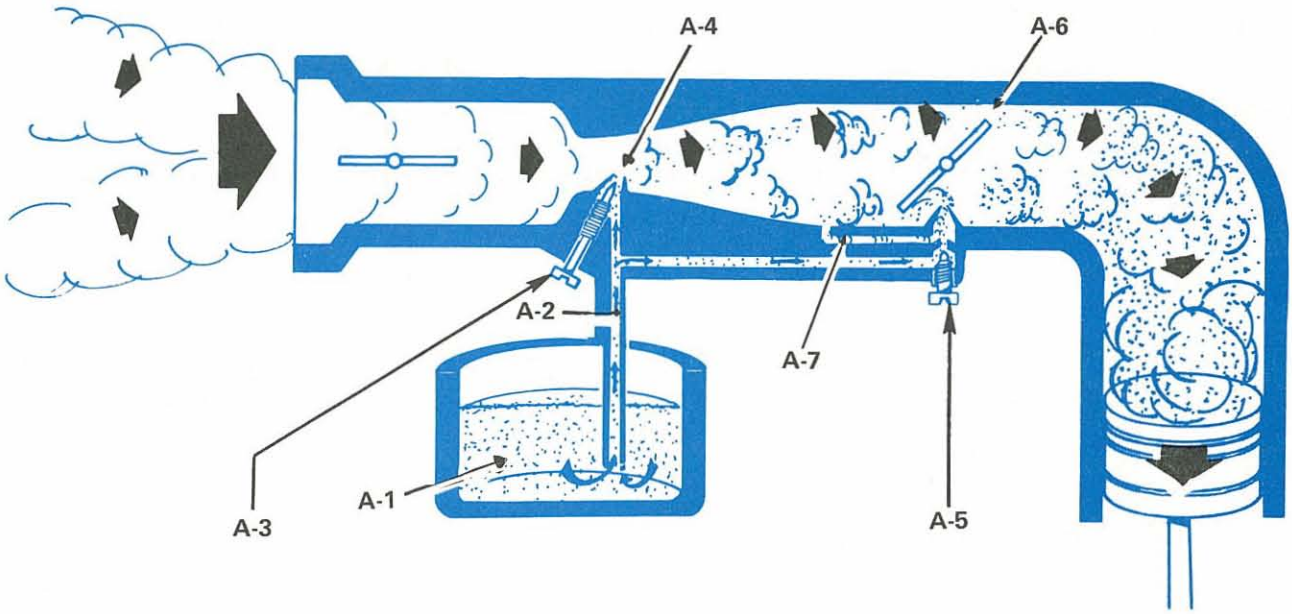


Figure 45

IDLE MIXTURE ADJUSTMENT

The Idle mixture valve is primarily for delivering fuel to the engine when it is idling and not under load. Notice how the Idle mixture valve is located on the engine side of the throttle valve shown at A-6. If this valve were closed the engine would continue to receive fuel and air would come from the air bleed shown at A-7. With the throttle valve closed the engine would receive only a limited amount of air and fuel. This mixture can be controlled by the idle mixture adjustment screw shown at A-5. If this screw is closed and the A-6 Throttle valve is closed, no fuel will reach the engine.

HIGH SPEED MIXTURE ADJUSTMENT

The high speed mixture adjustment screw shown at A-3 regulates the amount of fuel necessary for anything other than idle operation. On most carburetors these valves are used to adjust the amount of fuel being fed into the air stream. The amount of fuel allowed to enter through either the high speed mixture adjustment shown at A-3 or the idle mixture adjustment shown at A-5 will determine the fuel and air mixture required for most efficient operation.

JET ADJUSTMENTS

These mixture adjustments are commonly known as Jets. They are adjusted individually under the load they are designed for. Generally the high speed jet is adjusted first when the engine is at its operating speed. The jet is first turned all the way in and then backed off one complete turn. The engine is then brought up to its operating speed. The high speed jet can then be adjusted in and out until maximum speed is obtained.

If you turn the jet in and the engine begins to slow down you then try turning the screw out. The engine should then begin to speed up. After it reaches its maximum speed you can then turn the jet in the other direction and the engine should begin to slow down. Leave the jet set so the engine is operating at its maximum speed which is usually controlled by the governor.

After the high speed adjustment is complete set the throttle to the idle setting and adjust the idling jet the same way. There is a point in this adjustment where the engine will run at maximum idling speed.

TYPES OF FUEL SYSTEMS

There are three basic types of fuel systems used on small engines. We have already covered some of the basic principles of the gravity feed system and the suction lift system but we'll take a little more detailed look at how all three systems work.

GRAVITY FEED SYSTEM

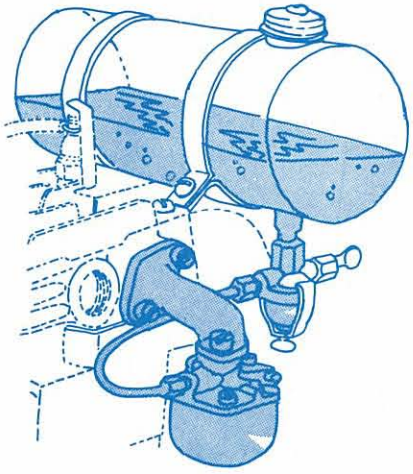


Figure 46

GRAVITY FEED SYSTEM

The most simple and widely used fuel system for small engines designed to be used in an upright position is the gravity feed system shown in Figure 46. The fuel tank is located above the carburetor and fuel flows by gravity through the fuel line to the carburetor. The amount of fuel entering the fuel bowl of the carburetor is controlled by the float valve that closes and opens the supply from the tank. As the engine needs more fuel the float valve opens and allows fuel to drain down from the tank. Most lawnmowers use this type fuel system.

SUCTION LIFT SYSTEM

In a suction lift fuel system fuel is drawn directly from the fuel tank into the carburetor. This system depends on atmospheric pressure for operation. Atmospheric pressure at sea level is about 14.6 pounds per square inch. This means there is about 14 pounds pressure on everything around us. A raise in altitude reduces this pressure. The higher the altitude the less the pressure. Fuel systems depending on atmospheric pressure must be adjusted differently at higher altitudes than ones used in lower altitudes.

Figure 47 shows how the suction lift system works. The atmospheric pressure shown at A-1 is about 14 pounds per square inch and is pressing down on the fuel as shown by the arrows. When air is sucked into the carburetor as shown at A-2 it is forced into the venturi area causing a low pressure area at A-3. This low pressure area actually creates a partial vacuum causing fuel to be drawn up through the opening shown at A-4. This partial vacuum is caused from the downward movement of the piston shown at A-5.

The fuel tanks on these fuel systems are mounted below the carburetor. Sometimes the fuel tank is attached to the carburetor and acts as the carburetor bowl.

SUCTION-LIFT FUEL SYSTEM

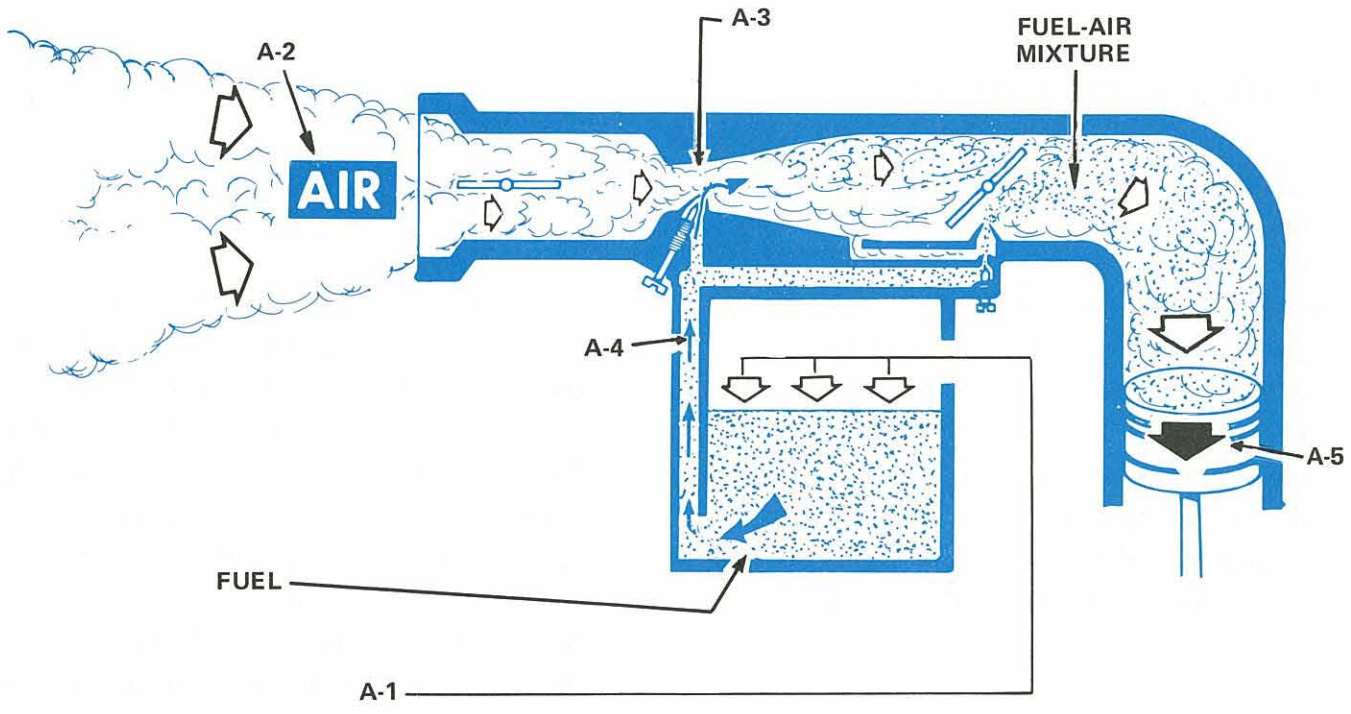


Figure 47

PRESSURE-FEED FUEL SYSTEM

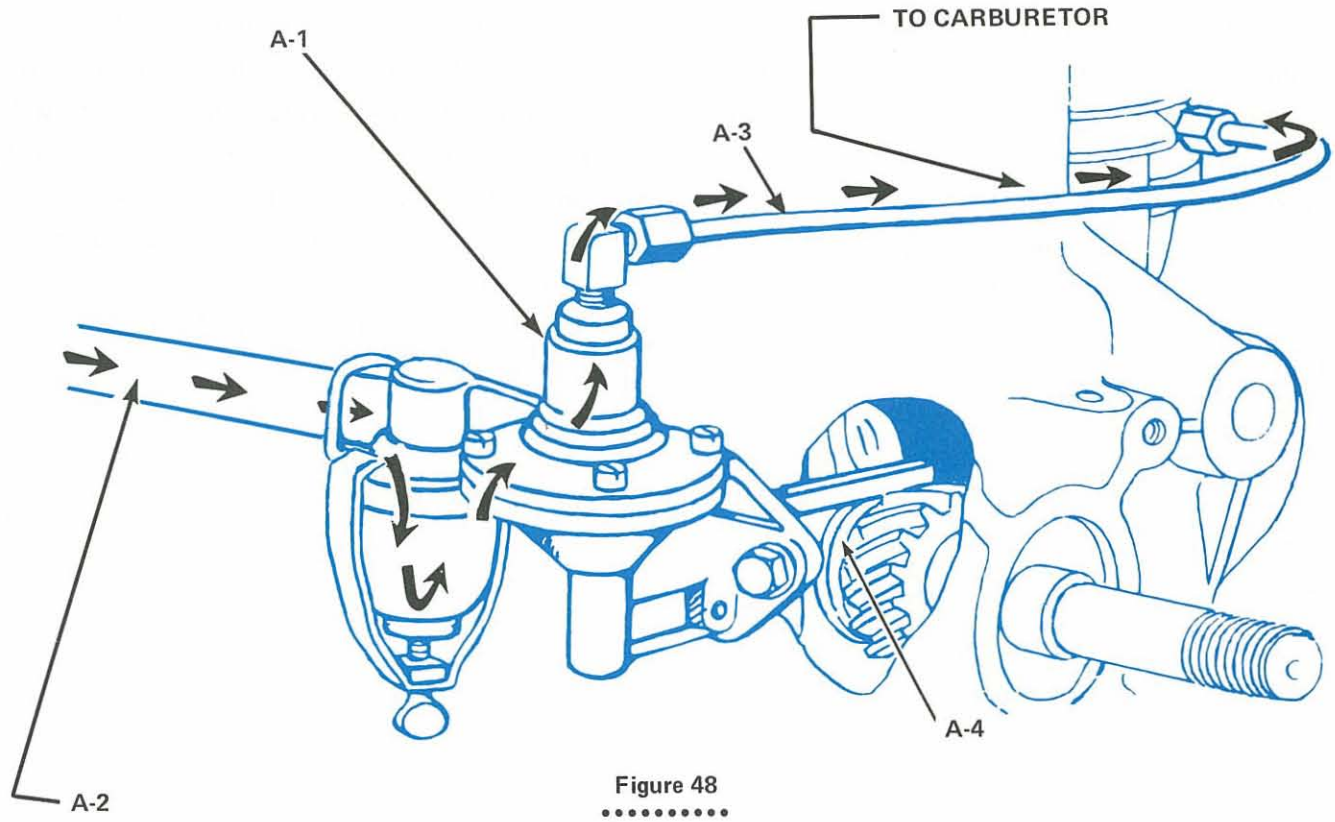


Figure 48

MECHANICAL FEED SYSTEMS

The mechanical, or sometimes called a pressure feed system, may have the fuel tank mounted either above or below the carburetor. It is installed between the tank and the carburetor. Figure 48 shows a typical mechanical feed system. This is the same basic design of fuel feed system used on many automobiles. The pump is shown at A-1. The fuel line A-2 goes direct to the fuel tank. Fuel comes from the tank and through the pump. It then goes through the line shown at A-3 and to the carburetor.

The pump is driven or operated from a cam either on the crankshaft or the camshaft as shown at A-4. We will go further into these fuel feed systems when we get into their application to the carburetor.

There are three basic types of carburetors used on most all small gasoline engines. The float type, suction lift and diaphragm carburetors are the three most commonly used on small engines. Their basic function is the same, however, their principle of operation is different. Each is designed for most efficient operation of the engine and its use. The outward appearance of these carburetors will often be different, even though they may be the same type of carburetor. Different manufacturers will change the outward appearance to fit their particular needs. All of the carburetor manufacturers use one or more of these basic designs.

This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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LESSON NO.(S) _____ _____
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(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

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INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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EXAMINATION ON LESSON 6
CARBURETION

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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The choke valve is used when starting a cold engine. ____
   TRUE
   FALSE

2. The venturi of a carburetor is the restriction inside of the passageway. ____
   TRUE
   FALSE

3. A mixture with too much fuel will cause incomplete combustion and reduce the amount of power output. ____
   TRUE
   FALSE

4. The types of carburetors found on most small engines are _____ . ____
   a. Float carburetor
   b. Diaphragm carburetor
   c. Suction lift carburetor
   d. All of the above

5. The choke valve regulates the amount of fuel and air allowed to enter the combustion chamber. ____
   TRUE
   FALSE

6. The gravity feed, suction lift, and pressure feed are the three basic types of fuel system used on small engines. ____
   TRUE
   FALSE

7. When the choke valve is closed, and the throttle valve is open, a lean mixture is allowed to enter the engine. ____
   TRUE
   FALSE

8. The basic function of the carburetor is to _____. ____
   a. Regulate the fuel and air mixture
   b. Break up the fuel into a fine mist
   c. Regulate the mixture into the combustion chamber
   d. All of the above

(Continued on page 2)

9. The throttle valve controls the amount of fuel and air mixture going into the combustion chamber. ___ ___
   TRUE
   FALSE

10. One function of the carburetor is to atomize the fuel or reduce it to a spray form. ___ ___
    TRUE
    FALSE

11. As the volume of air or liquid is forced through an opening, the pressure increases as the opening becomes smaller. _____
    TRUE
    FALSE

12. The idling speed adjustment is always adjusted first. _____
    TRUE
    FALSE

13. When fuel is combined with air, it forms a vapor that is inflammable. _____
    TRUE
    FALSE

14. On a two cycle engine, every upstroke is a power stroke. _____
    TRUE
    FALSE

15. Fuel tanks must be vented to prevent a vacuum from forming inside of the tank. ___ ___
    TRUE
    FALSE

16. The choke valve is always located on the engine side of the carburetor. _____
    TRUE
    FALSE

17. If a fuel mixture has too much fuel, it is referred to as too lean. ___ ___
    TRUE
    FALSE

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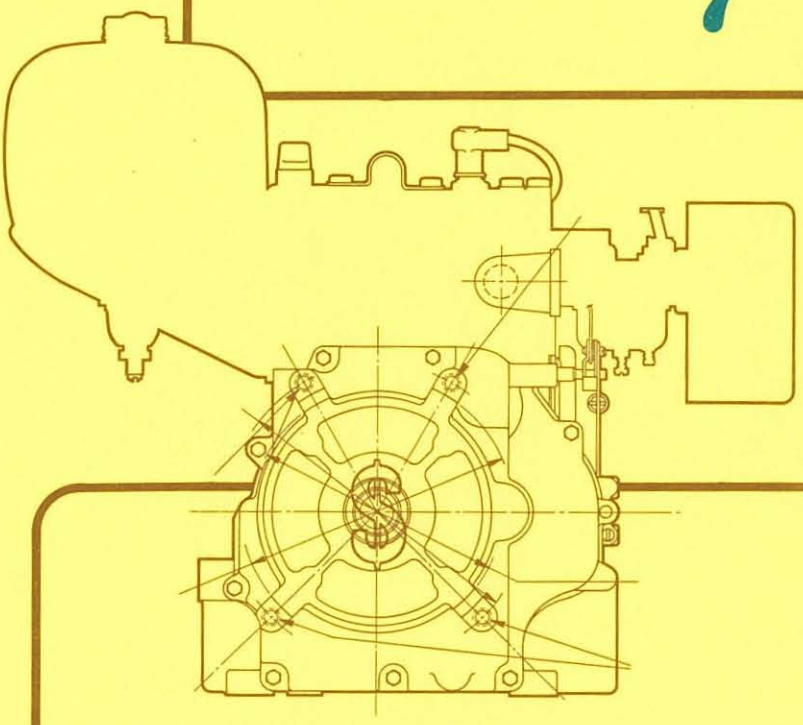
7



TURN THIS PAGE

...and let's find out all about --

FLOAT CARBURETOR PRINCIPLE

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FLOAT CARBURETOR

The float-type carburetor is one of the oldest in carburetor design but it is still widely used on small engines. They are called float carburetors because the fuel level in the fuel bowl is maintained by a float controlled valve.

Figure 49 shows the basic operating principles of the float-type carburetor. Fuel is drawn from the supply tank through the fuel line shown at A-1. There is a fuel valve shown at A-2 that allows fuel to enter. The valve is attached to the float shown at A-3. This float is set so it permits fuel to be maintained at a determined level in the fuel chamber shown at A-4. As fuel is used from this chamber the float drops down and opens the fuel valve allowing more fuel to enter at point A-2. When fuel reaches this level the float valve raises and restricts the flow of fuel. This carburetor must always be operated in an upright position to maintain fuel level.

FLOAT-TYPE CARBURETOR

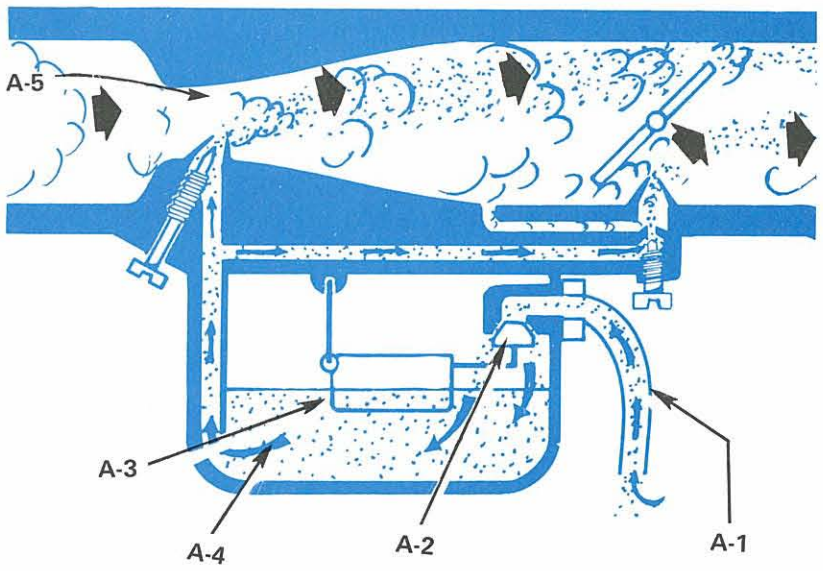


Figure 49

These are just the basic principles of the float operation of this carburetor. This carburetor must also have features for adjusting and regulating the amount of fuel and air mixture to meet the different conditions it will be used for.

The atmospheric pressure of the air on the fuel in the fuel chamber is about 14 pounds per square inch. This is known as 14 PSI. Due to the incoming air through the venturi as shown at A-5 a low pressure area is created at this point. This air pressure is less than 14 PSI and, in effect, creates a vacuum that will suction fuel from the fuel chamber.

There are four features we will have to add to this basic float carburetor to make it functional for most engine applications. It must have provisions for a constant load, sudden acceleration, idling and provisions for choking.

FLOAT CARBURETOR WITH CONSTANT LOAD

Let's take this same float carburetor design and add the first feature that will make it functional. Figure 50 shows a float carburetor with provisions for a constant load and speed. If this were the only thing needed for the engine operation a carburetor of this simple design could be used. Fuel comes from the supply tank at A-1. The float valve at A-2 allows fuel to enter the float chamber shown at A-3. The amount of fuel that is allowed to enter is controlled by the float bulb shown at A-4. The high speed load adjusting needle or valve is shown at A-5. This valve is adjustable to permit more or less fuel to enter. This is the valve that regulates the amount of fuel entering the engine for high speed operation.

With the limited provisions shown in this carburetor there would be no way it could operate if a sudden load were applied to the engine or if it were necessary to speed up the engine. There is no provision for a sudden engine load.

FLOAT-TYPE CARBURETOR
CONSTANT LOAD AND SPEED

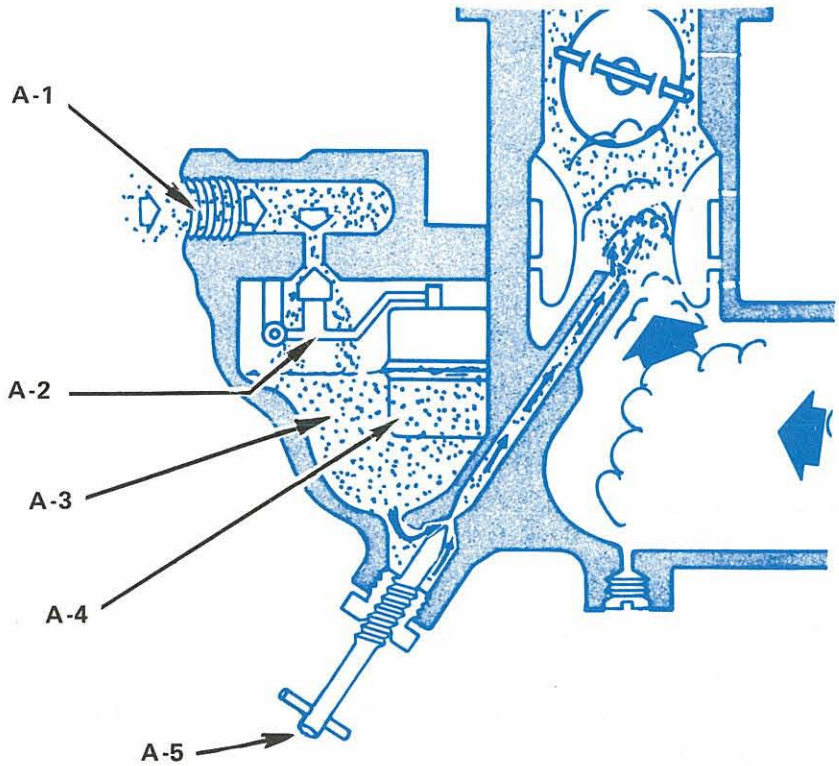


Figure 50

PROVISION FOR SUDDEN LOAD

When an engine requires an increase in power or speed more fuel and a richer mixture of fuel and air is required. Figure 51 shows how this reserve is provided. There is a reserve supply of fuel in an area called the accelerating well as shown in A-1. This is a compartment that surrounds the lower part of the fuel discharge nozzle assembly shown at A-2. This well remains full of fuel while the engine is operating under normal load. Anytime the engine requires a sudden demand for power the governor will open the throttle valve shown at A-3 and air will move past the nozzle much faster. This faster moving air will pick up additional fuel because it creates a low pressure area at that point near the tip of the fuel discharge nozzle.

The air bleed, shown at A-4, will have a higher pressure. This pressure difference forces fuel from the accelerating well at A-1 through the holes in the lower part of the fuel discharge nozzle assembly. It then goes out through the nozzle tip. This supplies a richer fuel mixture to the engine.

FLOAT-TYPE CARBURETOR
(PROVISION FOR SUDDEN ACCELERATION)

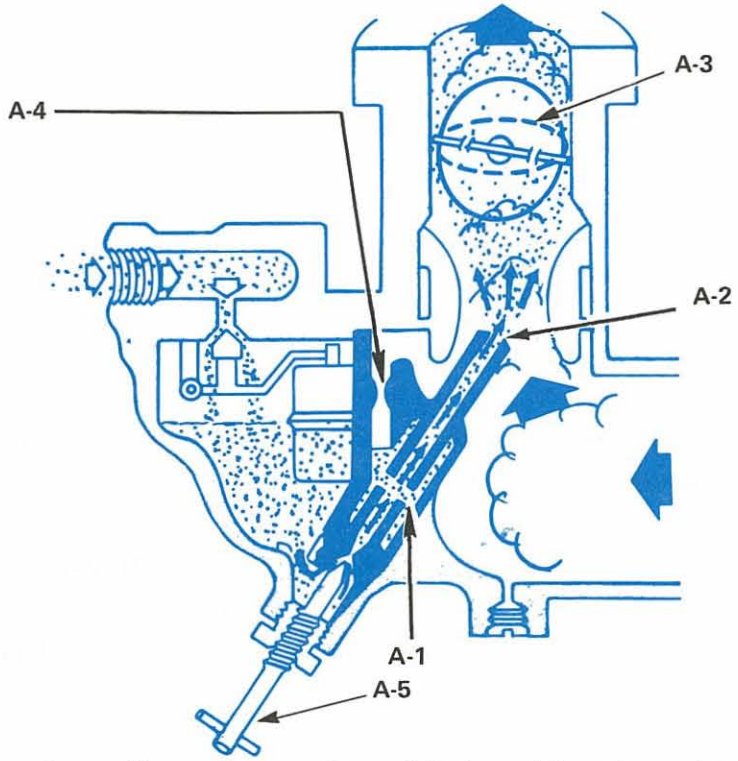


Figure 51

Without this accelerating well, an adequate flow of fuel would not be maintained from the carburetor float chamber. The engine would not receive adequate fuel when a sudden acceleration was needed. Immediately after the accelerating well is drained of fuel by the sudden need for acceleration from the engine it is refilled from the float chamber of the carburetor.

The high speed valve shown at A-5 provides a fuel-air ratio adjustment immediately after acceleration. If the heavy load continues, the fuel mixture does not have to be so rich. With the accelerating well empty, caused by a continuing heavy load, air will pass through the air bleed opening shown at A-4 into the accelerating well. It then mixes with the fuel going through the nozzle. This will reduce the richness of the mixture.

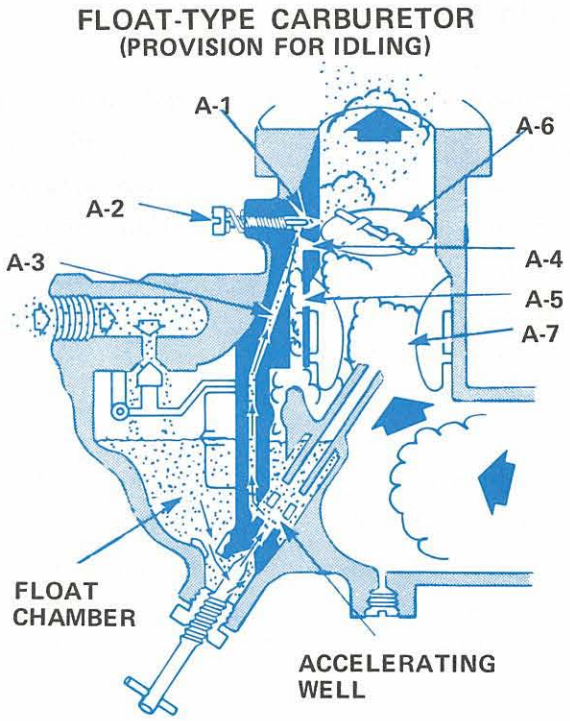


Figure 52

PROVISIONS FOR IDLING

So far in the build up of this carburetor we have provisions for constant high speed and sudden acceleration. If more features are added these same principles can be used and also allow the engine to run at idle speed.

Figure 52 shows the necessary features added to permit the engine to have the idling feature. We have added the upper idle port shown at A-1, the idle mixture adjusting screw shown at A-2, the idle fuel passage shown at A-3 and the lower port shown at A-4.

The throttle valve shown at A-6 is in the closed position. Air through the venturi at A-7 is not sufficient to produce the necessary low pressure area to draw fuel from the float chamber. To overcome this an additional fuel outlet is provided to bypass the throttle valve. This bypass is called the idle fuel passage and shown at A-3. This fuel outlet goes from the accelerating well to the upper idle port shown at A-1. This port is located just above the throttle valve and between the throttle valve and the engine. This outlet supplies fuel to the engine for idling. It is not dependent on the throttle valve since it completely bypasses this valve.

The size of this upper idle port determines the fuel flow it will deliver. Fuel coming from the idle passage at A-3 is mixed with air coming from the idle air bleed shown at A-5. This mixture then passes into the intake manifold through the upper idle port. This throttle valve can be completely closed and still receive fuel for idling providing the idle mixture adjusting screw shown at A-2 is not completely closed. There is also a lower idle port shown at A-4 that allows air to enter. This allows air and fuel to be mixed as it goes through the upper idle port and prevents an overly rich fuel mixture.

THROTTLE VALVE PARTLY OPEN

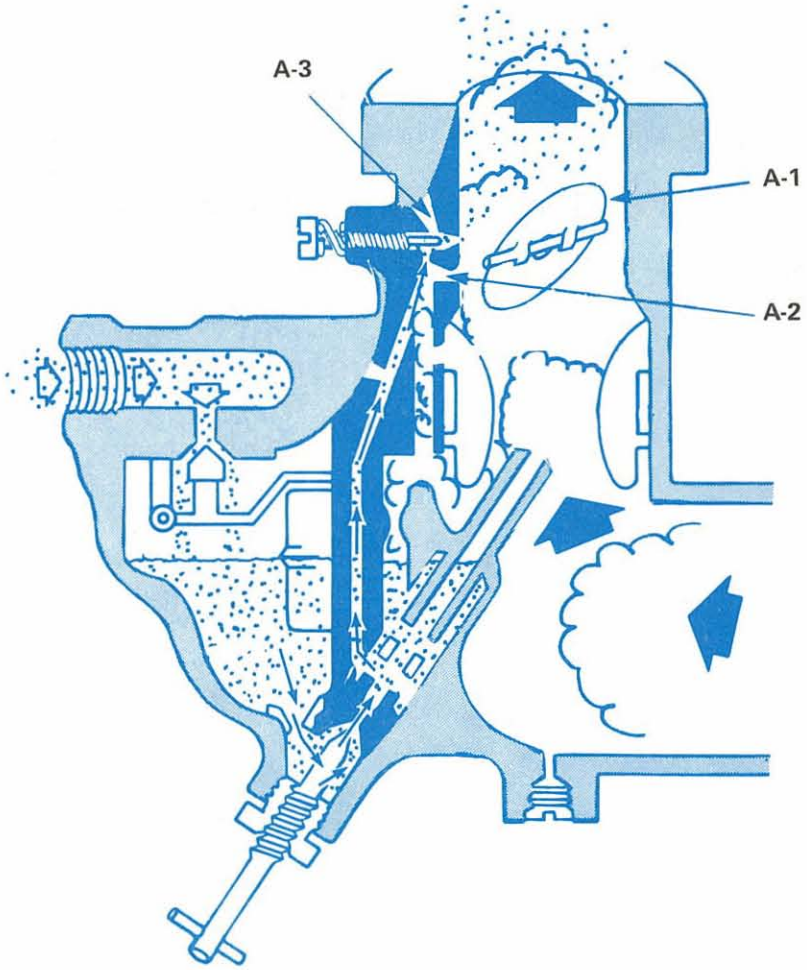


Figure 53

Figure 53 shows what happens when the throttle valve shown at A-1 is in the half-open position. This creates a low pressure area in both the lower idle port shown at A-2 and the upper idle port shown at A-3. Through these ports there is enough fuel mixture delivered to the engine to prevent a lean mixture when the throttle is open. If it wasn't for this extra supply coming from the lower port at A-2 the engine would starve for fuel when the throttle was slightly open.

When the throttle valve is full open, as shown in Figure 54, an additional low pressure is created causing the fuel nozzle, shown at A-1, to supply an additional amount of fuel necessary to operate the engine at full throttle.

The real function played by the lower idle port shown at A-2 and the upper idle port shown at A-3 when the throttle valve is open, is to supply an extra volume of fuel-air mixture until such time as the venturi action begins drawing fuel from the main fuel nozzle.

THROTTLE VALVE FULL OPEN

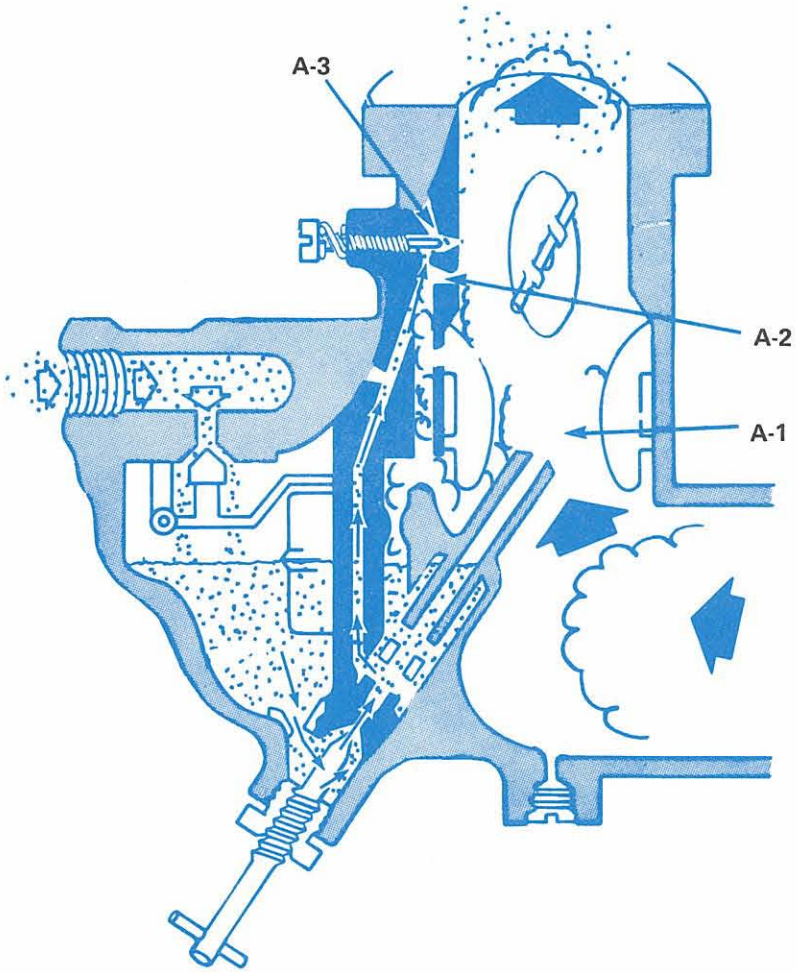


Figure 54

PRESSURE EQUALIZATION

Another feature on some float-type carburetors is the pressure equalization system. There is a series of air passages that connect the float chamber to the carburetor air inlet. This air chamber passes around the venturi of the carburetor and helps provide an equal air passage in both the carburetor and float chamber.

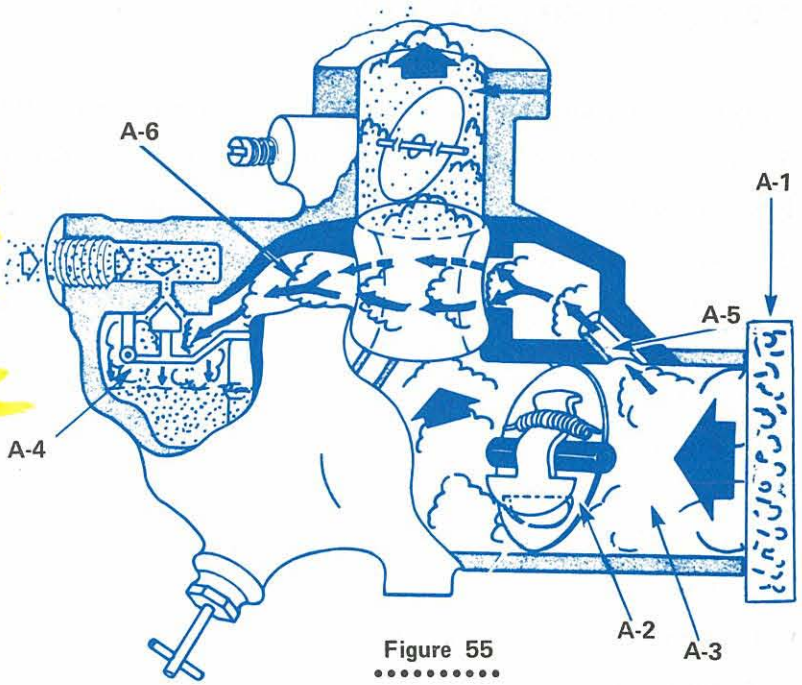


Figure 55

Figure 55 shows a typical arrangement of this air passage. This can be important in the carburetor design since there is a tendency for a low pressure area at the inlet side of the carburetor. This is due to the restriction of air caused by the air filter. A dirty air filter will increase this condition. The air filter is shown at A-1. The air enters on the choke side of the carburetor and is controlled by the choke valve shown at A-2.

For most efficient operation, we should have an equal air pressure in both the area of A-3 of the carburetor and A-4 of the float chamber. Without a pressure equalization system the fuel in the float chamber at A-4 would be exposed to atmospheric pressure which is about 14 pounds per square inch.

The atmospheric pressure at A-3 will be considerably less due to the restriction of the air movement caused by the air filter. If the pressure in the float chamber is more than the pressure in the carburetor the extra pressure would force extra fuel through the nozzle tip and cause the fuel mixture to be too rich. The fuel mixture would have too much fuel and not enough air.

This pressure equalization is accomplished by a series of passages as shown at A-5 and A-6. Through a series of holes drilled in the housing of the carburetor a direct air passage is provided between these two points. These air passages are directed around the venturi and not through it.

There are some float type carburetors which are vented to the atmospheric pressure through a small hole in the carburetor housing, however, most of them use the air passage method.

AIR PASSAGE CONSTRUCTION

To get a better idea of how these air passages operate we will take a look at their construction. See Figure 56. Suppose we need to get an air passage between points A-1 and A-2 without going through the venturi. First we would drill a small hole between points A-4 and A-2. This hole could go through any part of the opening at A-2 depending on the design of the carburetor.

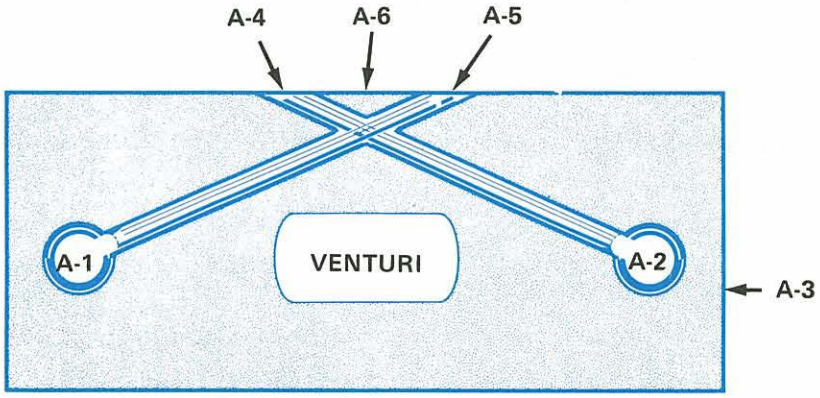


Figure 56

Next a hole is drilled at point A-5 until it enters the hole at A-1. The hole stops as soon as it has entered one side of this area. Notice that these holes cross at point A-6. A-1 and A-2 are connected together, however, they are both exposed to the outside of the carburetor at A-4 and A-5. If both of these holes were closed at A-4 and A-5 we would have a direct passage between A-1 and A-2 without going through the venturi. Notice the hole does not continue to point A-3. The holes at A-4 and A-5 can easily be closed with a Welch plug making a complete passage between A-1 and A-2.

WELCH PLUG

A welch plug is used primarily to conceal an opening made for some manufacturing reason. They are made of soft metal formed in round dish shape, as shown in Figure 57. A-1 shows the welch plug in its original shape. They are made in a number of different sizes. When this plug is inserted in the proper size hole it fits just a few thousandths of an inch less than the diameter of the hole. After it is installed in the hole, pressure is applied at point A-2 with a flat punch and tapped in the center. This expands the plug as it flattens and makes an air tight seal in the hole.

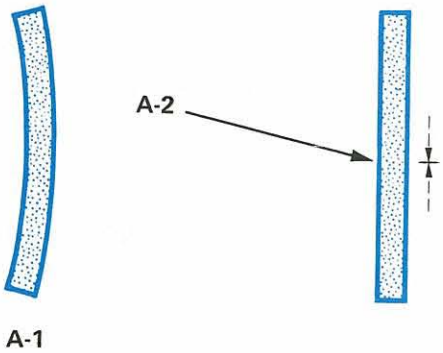


Figure 57

One very common use of the welch plug is in the application of air or fuel passages. They are used basically as part of the manufacturing process of the engine but are also used as cleanout ports for cleaning the air or fuel passages.

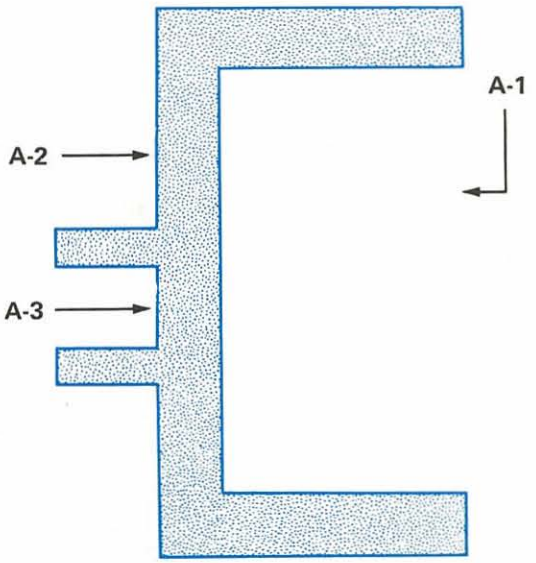


Figure 58

Figure 58 shows a cross section of a part of an engine casting. All the open area shown at A-1 may be solid metal when the engine casting is made. This area is then drilled out so the part of the casting will look like Figure 58. Now, suppose it was necessary to provide an air passage to points A-2 and A-3.

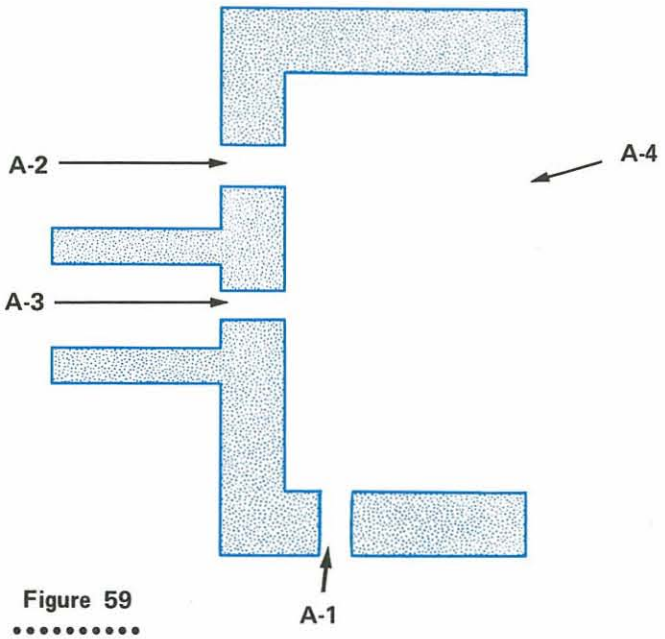


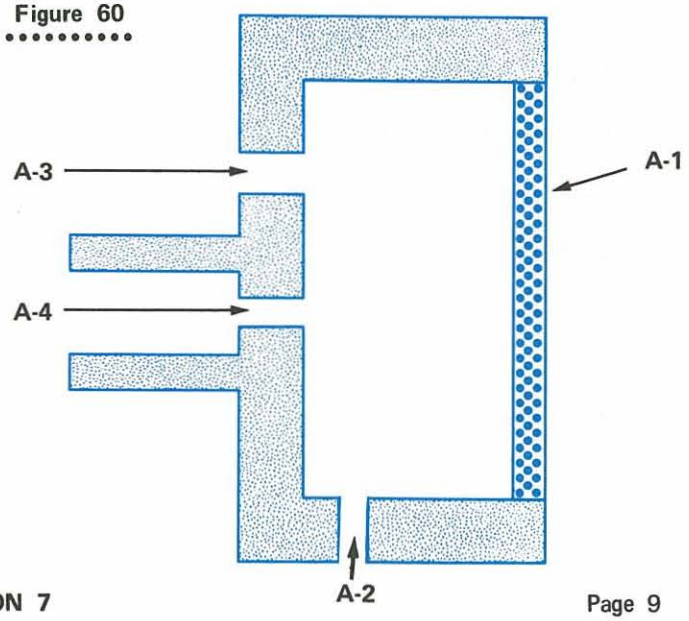
Figure 59

Figure 59 shows this same part of the engine casting with three holes drilled in it. Air could enter at point A-1 and go direct to a part of the carburetor shown at A-2 or it could go to the part of the carburetor shown at A-3, but it would also escape out to the open end at A-4. Remember in the manufacturing of this part of the carburetor casting a hole has been drilled at points A-1, A-2, A-3 and A-4. A-2 and A-3 go to different parts of the carburetor.

Figure 60 shows this same part of the carburetor casting after the welch plug has been installed. Point A-1 shows the welch plug covering the opening in the casting. Air can pass through point A-2 and go direct to both A-3 and A-4 parts of the carburetor.

This is basically the same engineering theory as the air passages shown in Figure 56. It is just an alternate method and often both methods are used in combination. Welch plugs and air passages can be used on all types of carburetors.

Figure 60



CHOKE

The function of the choke is to restrict the amount of air entering the carburetor to provide an extra rich fuel mixture. Some chokes are opened and closed automatically and some are manual. When you choke an engine you close the choke valve so the air supply is almost cut off. The little air that is supplied passes around the edges of the choke valve or through a special opening sometimes made as part of the valve. This is sometimes made similar to a hinge type opening as shown in Figure 61. Sometimes the hinged part shown at A-1 is not used and a small cutout is left which does not allow for complete full choking. Complete full choking is seldom necessary. This is known as the butterfly type valve choke.

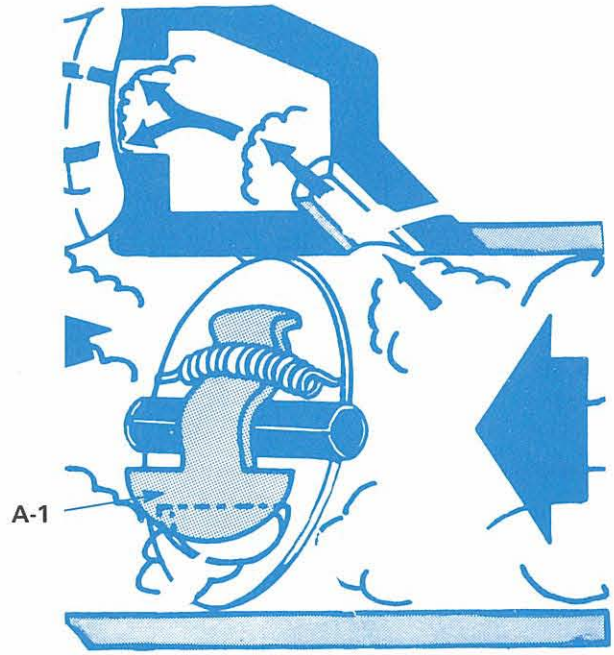


Figure 61

Another type of choke is shown in Figure 62. It has the same basic principle of operation except a sliding type valve is used. Air enters through the filter at A-1 and when the choke is open it will go direct to the carburetor as shown at A-2. The closed position is shown at A-3. This type choke can generally be positioned at any opening point and will stay in place until moved manually. Manually operated chokes of the butterfly type are generally designed to latch into the fully open or fully closed position. Some are spring-loaded in the open position and it is necessary to hold closed for starting.

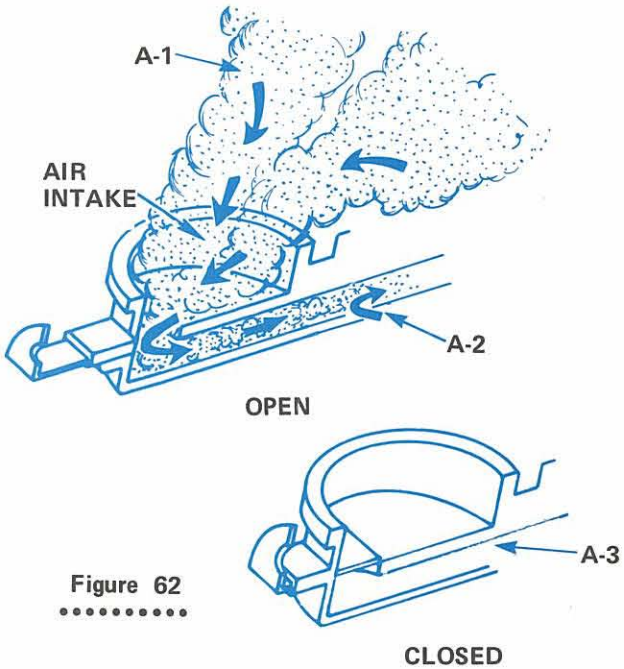


Figure 62

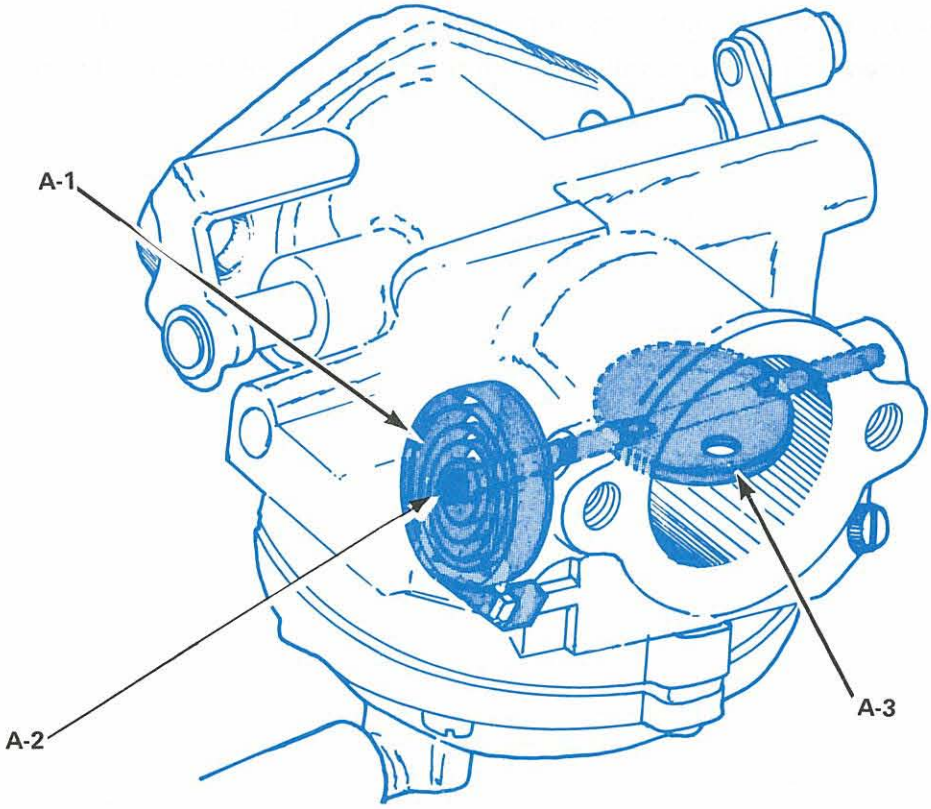


Figure 63

AUTOMATIC CHOKES

Automatic chokes operate on the same basic principle as the thermostat. Figure 63 shows a typical automatic choke design. Most automatic chokes operate on the principle that when metal is heated it expands and when it cools it contracts. The coil spring shown at A-1 is mounted or attached direct to the engine, generally near the exhaust manifold which is the first part that begins to absorb heat build-up when the engine is started. The inside end of this coil spring is anchored to the choke valve stem at A-2. As the temperature of the engine changes, the spring will expand or contract. As the spring expands or contracts in length it will open or close the choke valve shown at A-3. It is adjusted to open when the engine gets warm and to close when the engine cools.

PRIMER

Some engines use a pressurized primer instead of a choke valve. Others have both the primer and choke valve. A primer is a type of pump that will allow you to actually force extra fuel into the carburetor intake.

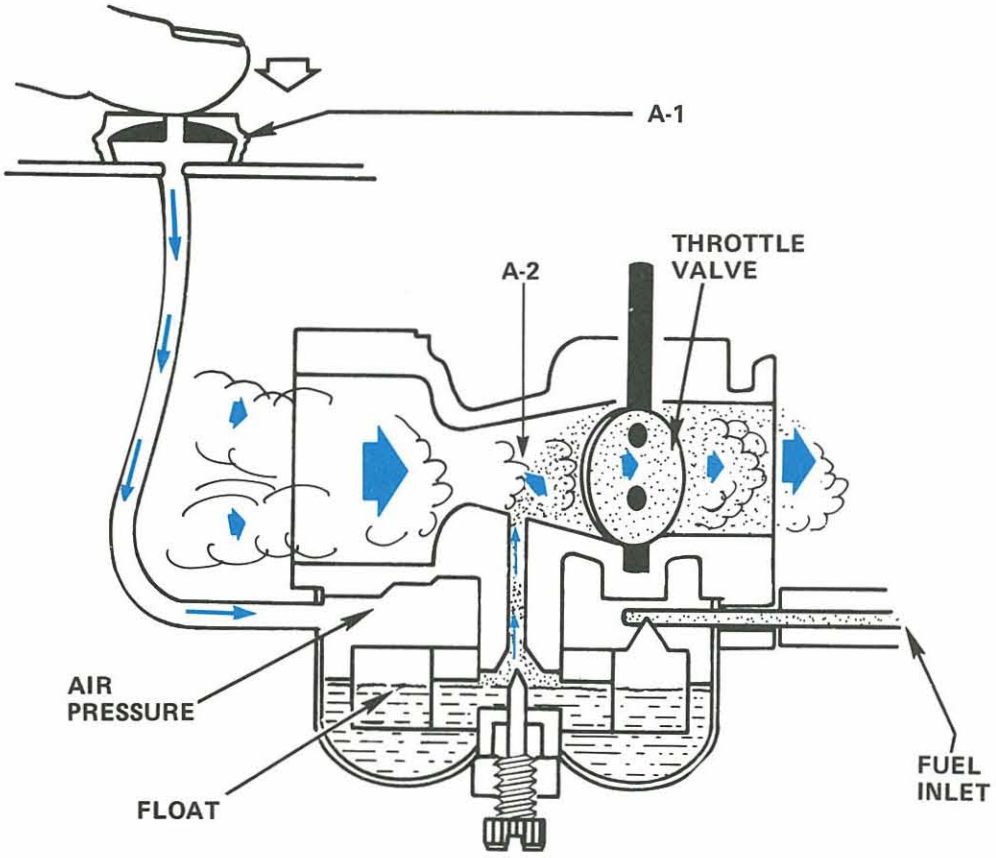
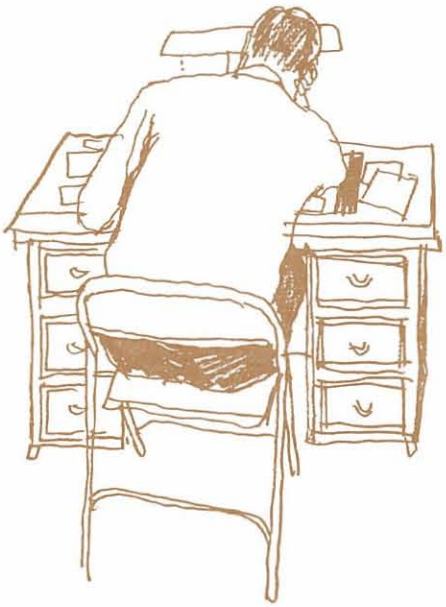


Figure 64

Figure 64 shows a typical primer operation without a choke valve. This principle of using the primer instead of a choke valve is used very extensively on multi-purpose engines designed to operate equipment in different positions, such as chain saws.

When the primer bulb shown at A-1 is depressed, fuel is forced directly from the carburetor float bowl into the venturi of the carburetor as shown at A-2. This direct forcing of fuel from the float bowl into the carburetor gives a rich fuel starting mixture. The basic principle of the primer operation is to force raw fuel directly into the venturi area. Basically it is the same as reducing the fuel air mixture by restricting the flow of air coming into the carburetor with the choke butterfly valve.

Before we go into float carburetor repair we should be familiar with exploded view drawings showing how carburetors and other engine components are assembled.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 7
FLOAT CARBURETOR PRINCIPLE

FOLEY-BELSAW INSTITUTE OF
SMALL ENGINE REPAIR
6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The accelerating well in the float carburetor is refilled from the venturi area of the carburetor. _____
   TRUE
   FALSE

2. In carburetor construction, a _____ is used to close or conceal an opening made during manufacturing. _____
   a. Welch plug
   b. Cap
   c. A valve

3. When an engine requires an increase in power or speed, more fuel and a leaner mixture of fuel and air is required. _____
   TRUE
   FALSE

4. For most efficient operation, a float carburetor should have equal air pressure between the float bowl level and the intake side of the carburetor. _____
   TRUE
   FALSE

5. The float permits fuel to be maintained at a predetermined level in the venturi. _____
   TRUE
   FALSE

6. Some engines use a _____ instead of a choke valve. _____
   a. Venturi
   b. Throttle valve
   c. Pressurized primer

7. Float carburetors have a reserve supply of fuel in an area called the accelerating well. _____
   TRUE
   FALSE

8. Most automatic chokes on small engines operate on the principle that when metal is heated it expands and when it cools it contracts. _____
   TRUE
   FALSE

(Continued on page 2)

9. The accelerating well in float carburetors remains full when the engine is operating under normal load.
   TRUE
   FALSE

10. Fill in the letters showing the location of the basic carburetor parts or functions as they relate to Fig. 7-1.
    float
    venturi
    fuel drawn in from supply tank
    fuel chamber
    valve allowing fuel to enter fuel chamber

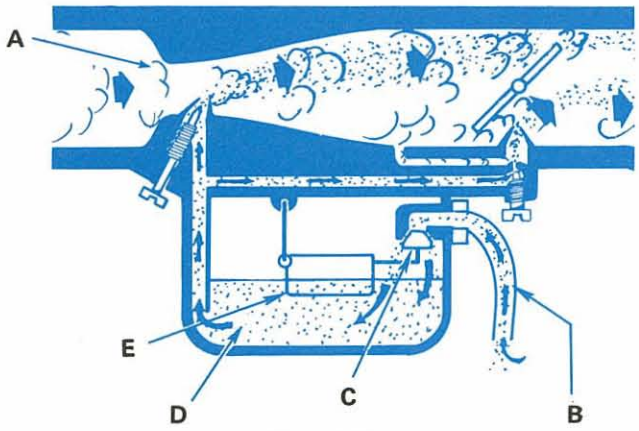


Figure 7-1

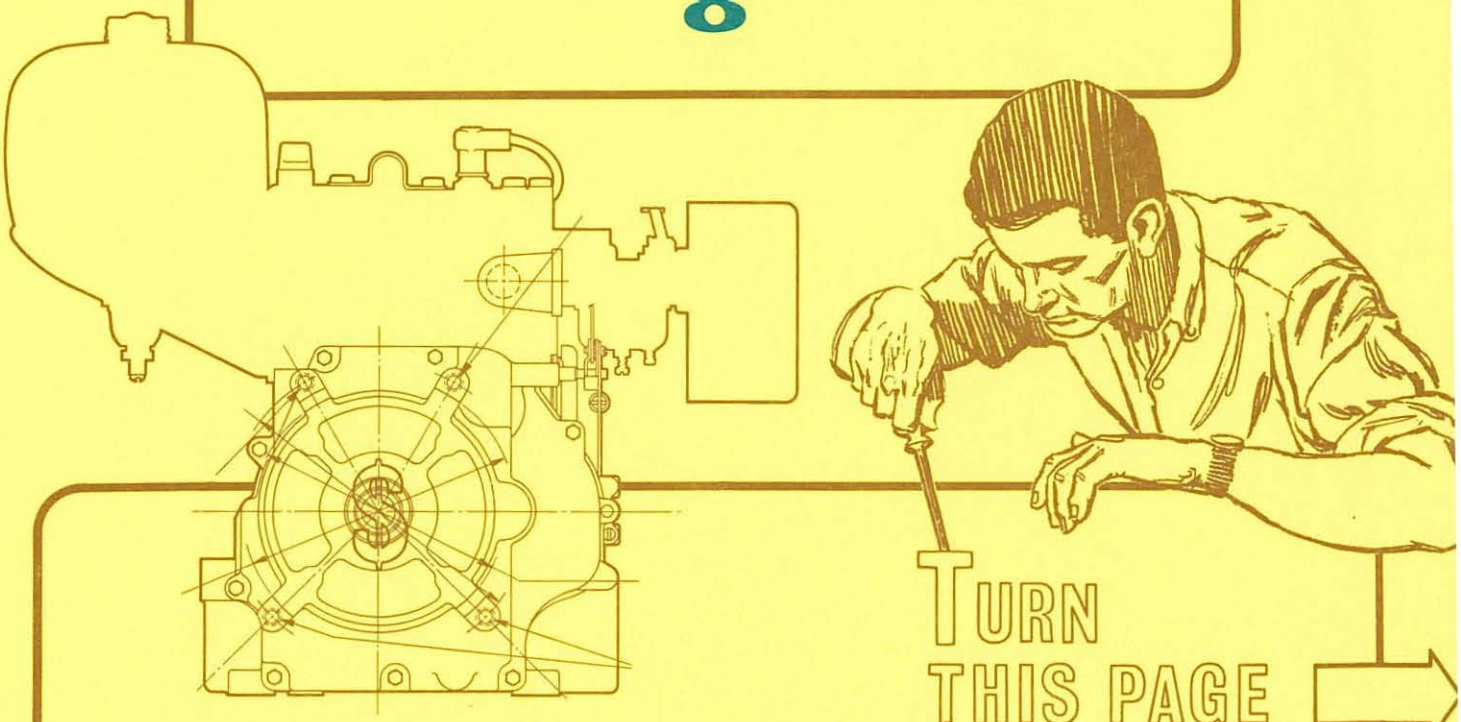
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

8



TURN THIS PAGE

...and let's find out all about -- DRAWINGS,

PART NUMBERS AND FLOAT CARBURETOR REPAIR

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EXPLODED VIEW DRAWINGS

One very important feature of the small engine repair business is parts identification. Some parts catalogs contain hundreds of parts and drawings for the many different engine models. Many of these parts are the same and interchangeable, however, there will be exploded view drawings of each different number. If an assembly, such as the carburetor, has some minor variations in its basic design, new drawings and parts list are printed to cover it. These manufacturers' catalogs are sometimes quite large, containing hundreds of pages and can be difficult to read and identify parts if you are not familiar with their structure and make-up. Later in the course we'll cover in detail the construction of these catalogs or parts manuals, as they are known.

In order to use the parts manual, it is first necessary to have some knowledge of exploded view drawings and how to read them. You have probably seen these drawings or parts lists that come with some pieces of machinery or other items you have purchased. They become a little more difficult to read when they cover all the parts of a large unit with many parts, such as an engine.

These exploded view drawings can also be a great help in the assembly of an engine or any part of an engine since the drawings are made to show the reassembly sequence of the individual parts. Each part is shown in the order in which it is reassembled. Every part must be accounted for in the order in which it is installed. This will eliminate left over parts which often happens in reassembly.

Some of the references we will be working with in the future lessons will be exploded view drawings.

Figure 65 shows a typical exploded view drawing of a float carburetor used on many small engines. In an exploded view drawing all the component parts are shown in relationship to the principle or main part of the assembly. This is usually the largest part that the other parts attach to. Often there will not be any individual body part, just the order in which all parts are related to each other.

In the case of the float carburetor, shown in Figure 65, the main part would be the one shown at Number 9 which is known as the body assembly. In this case this would be the base casting or machined part from which the assembly started. All holes and machining would first be completed on this part to receive the other working parts.

EXPLODED VIEW DRAWINGS

Sometimes the same reference number will be used one or more times, such as the Number 8 springs. This means it is the same spring but is used in more than one place in the assembly. A reference number may point to more than one part which indicates that these parts are available as an assembly. This is sometimes necessary because of manufacturing and assembly procedure. In some cases, such as needles and seat valves, they should always be replaced as an assembly. By following the dotted lines from one part to another every part would be reassembled in the order shown. Starting at the bottom, the needle assembly would be installed with the Number 22 "O" ring first going on the needle, then the nut shown at 21 and the Number 20 gasket.

All of these parts would be installed in the hole in the bottom of the bowl. Notice Number 17 shows parts going to both the top and the bottom of the bowl. This is the order in which these parts are installed. The Number 16 stem assembly for the bowl drain goes on the inside of the bowl and the Number 18 spring and Number 19 retainer go on the bottom outside of the bowl. Notice there are two Number 20 gaskets. One goes inside the bowl and the other on the bottom outside.

If you follow the dotted line from the Number 21 needle assembly, it goes direct to the Number 23 main nozzle. It screws into the main nozzle and is the high speed needle valve adjustment. The Number 23 main nozzle goes directly into the Number 9 body assembly.

Before the Number 17 bowl assembly can be installed the Number 14 float must be installed along with the Number 13 valve, valve seat and gasket. These are another group of parts that should be replaced as a unit and not separately. Notice the dotted line coming from the Number 12 gasket. It goes to a different part of the carburetor body.

Let's look at the Number 1 shaft and lever assembly in the top part of the drawing. There is a line showing the hole in the body assembly this part goes in. After the Number 1 shaft and lever is inserted, the Number 3 throttle shutter is installed inside the carburetor body and then the Number 2 screw holds it in place on the Number 1 throttle shutter shaft. The Number 4 shaft and lever assembly for the choke is installed the same way, except the Number 5 return spring is first slipped on the shaft. Next the Number 10 choke shutter is attached to the choke shaft with the Number 2 screw. If every part is assembled in the order shown in this drawing the carburetor would be completely assembled.

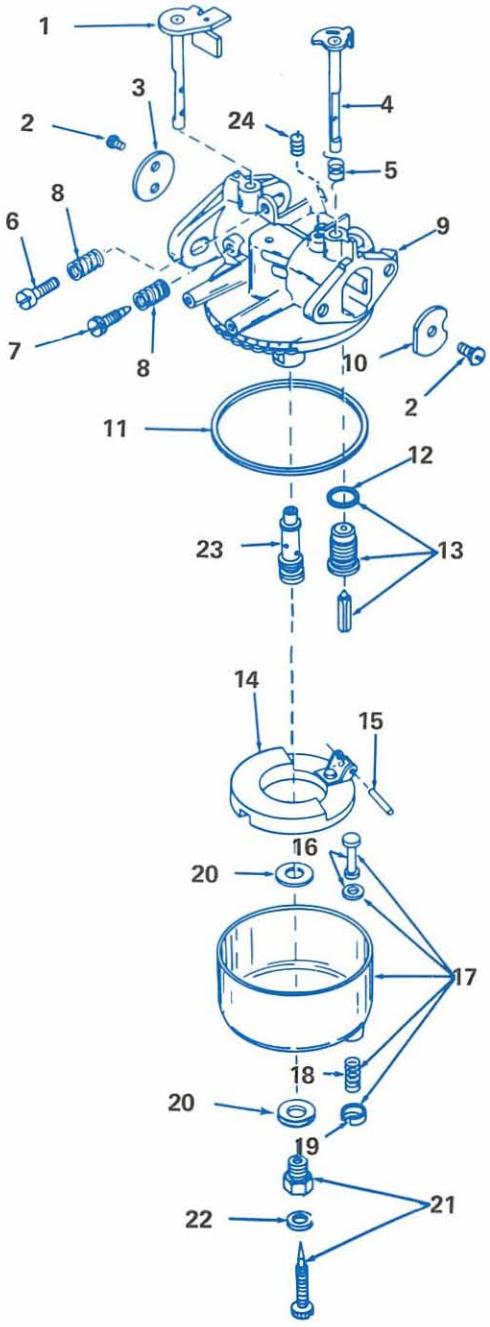

Figure 65

Figure 66 shows the reference number, part number and part name of all parts shown in Figure 65. It would be a good idea to study this carefully and be able to locate each part on the drawing. Notice some of the part numbers are marked with an asterisk (*). There will always be a footnote at the bottom of the catalog page showing what this means.

Sometimes there will be more than one asterisk but the explanation or the reason will always be given at the bottom of the page.

Figures 65 and 66 show one of the simple forms of exploded view drawings and their description. Often these drawings are more complex and require more than just the two-directional approach shown in Figure 65. One exploded view drawing will often cover a number of different models of the same unit. Everytime there is an engineering change in design of a unit even though it is very small, the unit receives a new model number.

Figures 65 and 66 show an exploded view drawing and parts list of what would be the basic model of this particular carburetor. As this basic carburetor is improved or adapted to meet the needs of different applications, minor changes are necessary to meet the application it is to be used for.

REFERENCE NUMBER	PART NUMBER	PART NAME
1	28236	Shaft & Lever Assy., Throttle
2	630606	Screw, Sems, 4-40 x 3/16
3	27553	Shutter, Throttle
4	27135	Shaft & Lever Assy., Choke
5	27787	Spring, Choke return
6	630605	Screw, Throttle adjustment
7	*27112	Needle, Idle
8	27114	Spring, Adjustment needle
9	28235	Body Assy., Carburetor
10	27541	Shutter, Choke
11	*27109	Gasket, Bowl-to-body
12	27108	Gasket, Seat
13	*29154	Valve, Seat & Gasket Assy. (Incl. Number 12)
14	27105	Float
15	*27106	Shaft, Float
16	27136	Stem Assy., Bowl drain
17	27101	Bowl Assy. (Incl. Numbers 16, 18 & 19)
18	27137	Spring, Bowl drain
19	27138	Retainer, Bowl drain stem
20	*27110	Gasket, Bowl-to-body
21	*27111	Needle Assy., Power adjusting (Incl. Number 20)
21	*28945	Needle Assy., Power adjusting (Incl. Number 22)
22	*27544	"O" Ring
23	**29139	Nozzle, Main
24	27113	Spring, Choke stop

Figure 66

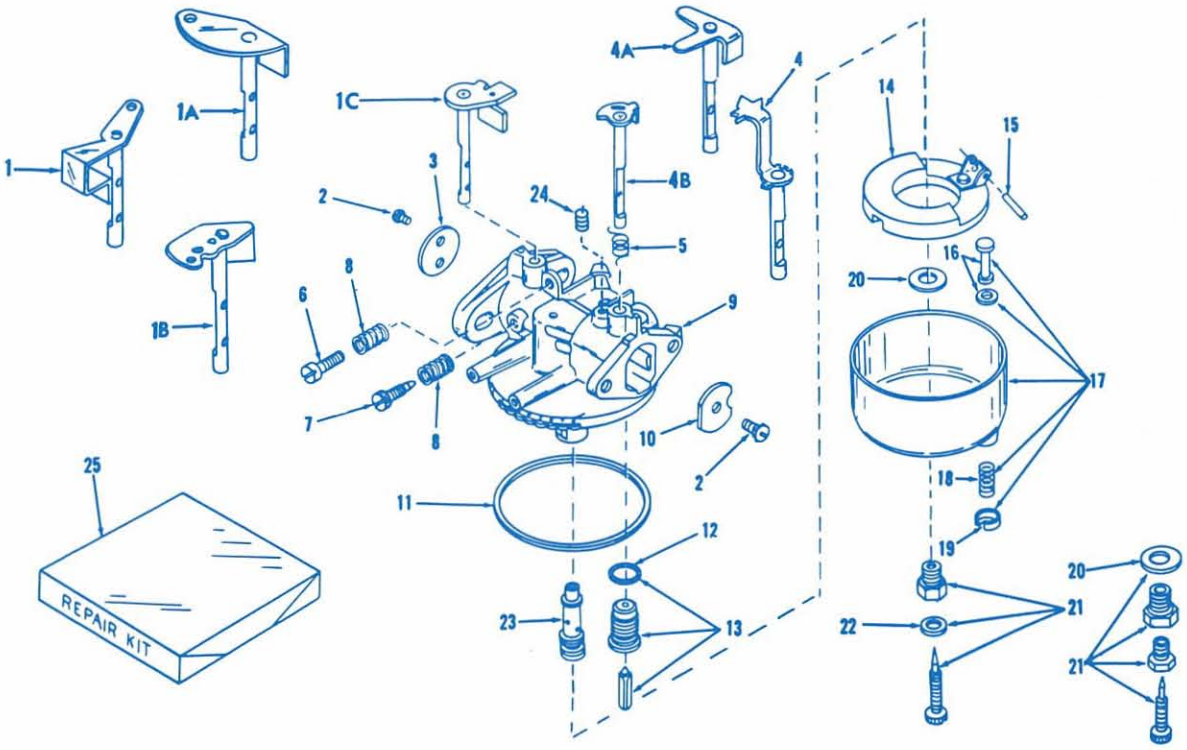

Figure 67

Figure 67 shows an exploded view drawing of a carburetor, however, this drawing shows the necessary parts to fit thirteen different model carburetors. These are all the same basic carburetor and operate the same way, however, some of the parts are designed just a little different.

Compare Figure 67 with Figure 65 and you will notice the two basic differences in these drawings. Note that in Figure 67 the float bowl assembly Numbers 17 and 21, are in a different position, however, the dotted line connecting these two sub-assemblies shows the reassembly sequence the same as in Figure 65.

If you will compare these two drawings carefully you will see there are more parts included in Figure 67. In the top left part of the drawing in Figure 67 there are reference numbers 1, 1A, 1B and 1C. This is the throttle shaft and lever. Only one of these three parts is used with the carburetor. The same with numbers 4, 4A and 4B. Only one of these parts is used with each carburetor. The shape of the part to fit the particular application is the basic difference. Its function in the carburetor remains the same.

PART NUMBERS AND MODELS

An individual part number may fit one or more models. Figure 68, Page 6, shows the reference number, part number and part name of the parts shown in Figure 67 along with the model number of the carburetor they will fit. Notice reference Number 1 is part number 28236. This shaft and lever assembly will fit carburetors with model numbers 28234 and 28415. Reference Number 1A is part number 28871 and will fit carburetors with model numbers 28249, 28815, 28860, 28922 and 28959.

Reference Number 1A also has a part number 27551. This means that there are actually two different parts but since their appearance is very similar only one view of it is shown in the drawing. This part fits carburetor models 28302 and 28382. Reference number 1B is part number 28636 and fits carburetor models 28626 and 28627. Reference number 1C is part number 29171 and fits model numbers 29168 and 29237. If you will notice there is an "X" mark under each model number. Each reference and parts number will fit one or more of these model numbers.

RELATED DRAWINGS

It is not practical to have exploded view drawings of the entire engine unless they are very large. In most cases, an individual part or assembly drawing is required for parts identification and assembly sequence. For this reason, a master or complete drawing is furnished showing the complete engine assembly with all parts and sub-assemblies in as near their working location as possible.

Figure 69, Page 7, shows an exploded view drawing of a complete engine. All parts are in their sequence of assembly as near as possible, however, there are some variations since this engine shows three different styles of carburetors.

Numbers 196, 196A and 196B show three different carburetor units only. There are no individual parts breakdown. All three of the basic carburetor units are used on this same type of engine. It would be impractical to show a complete breakdown on each of these carburetor units. They are shown complete with a reference number to the proper exploded view drawing of this individual carburetor. Other common assemblies of this engine would carry a separate drawing. In order to see how this carburetor is constructed or order parts for it, it would first be necessary to identify the type carburetor on the engine. All three of these carburetors have different shapes so it would not be difficult to determine which type was on the engine.

CARBURETOR NUMBERS
28234, 28249, 28302, 28382, 28415, 28626, 28627, 28815, 28860, 28922, 28959, 29168, 29237

REF. NO.	PART NO.	PART NAME	CARB. NOS. 28234	28249	28302	28382	28415	28626	28627	28815	28860	28922	28959	29168	29237
1	28236	Shaft & Lever Assy., Throttle	X				X								
1A	28871	Shaft & Lever Assy., Throttle		X						X	X	X	X		
1A	27551	Shaft & Lever Assy., Throttle			X	X									
1B	28636	Shaft & Lever Assy., Throttle						X	X						
1C	29171	Shaft & Lever Assy., Throttle												X	X
2	630606	Screw, Sems, 4-40 x 3/16	X	X	X	X	X	X	X	X	X	X	X	X	X
3	27553	Shutter, Throttle	X	X	X	X	X	X	X	X	X	X	X	X	X
4	27135	Shaft & Lever Assy., Choke	X	X		X	X			X					
4	28923	Shaft & Lever Assy., Choke										X			
4A	27778	Shaft & Lever Assy., Choke			X						X		X		
4B	28637	Shaft & Lever Assy., Choke						X	X					X	X
5	27787	Spring, Choke return			X			X	X		X		X	X	X
6	630605	Screw, Throttle adjustment	X	X	X	X	X	X	X	X	X	X	X	X	X
7	*27112	Needle, Idle	X	X	X	X	X	X	X	X	X	X	X	X	X
8	27114	Spring, Adjustment needle	X	X	X	X	X	X	X	X	X	X	X	X	X
9	28235	Body Assy., Carburetor	X												
9	28880	Body Assy., Carburetor		X											
9	28653	Body Assy., Carburetor			X				X		X				
9	28464	Body Assy., Carburetor				X				X		X			
9	28477	Body Assy., Carburetor					X								
9	28642	Body Assy., Carburetor						X							
9	28962	Body Assy., Carburetor											X		
9	29169	Body Assy., Carburetor												X	
9	29238	Body Assy., Carburetor													X
10	27541	Shutter, Choke	X	X		X	X			X					
10	27786	Shutter, Choke			X			X	X		X		X		
10	28924	Shutter, Choke										X		X	X
11	*27109	Gasket, Bowl-to-body	X	X	X	X	X	X	X	X	X	X	X	X	X
12	27108	Gasket, Seat	X	X	X	X	X	X	X	X	X	X	X	X	X
13	*29154	Valve, Seat & Gasket Assy. (Incl. No. 12)	X	X	X	X	X	X	X		X	X	X	X	X
13	*29156	Valve, Seat & Gasket Assy. (Incl. No. 12)								X					
14	27105	Float	X	X	X	X	X	X	X	X	X	X	X	X	X
15	*27106	Shaft, Float	X	X	X	X	X	X	X	X	X	X	X	X	X
16	27136	Stem Assy., Bowl drain	X	X	X	X	X	X	X	X	X	X	X	X	X
17	27101	Bowl Assy. (Incl. Nos. 16, 18 & 19)	X	X	X	X	X	X	X	X	X	X	X		
17	29170	Bowl Assy. (Incl. Nos. 16, 18 & 19)												X	X
18	27137	Spring, Bowl drain	X	X	X	X	X	X	X	X	X	X	X	X	X
19	27138	Retainer, Bowl drain stem	X	X	X	X	X	X	X	X	X	X	X	X	X
20	*27110	Gasket, Bowl-to-body	X	X	X	X	X	X	X	X	X	X	X	X	X
21	*27111	Needle Assy., Power adjusting (Incl. No. 20)	X	X	X	X	X	X	X	X	X		X		
21	*28945	Needle Assy., Power adjusting (Incl. No. 22)										X		X	X
22	*27544	"O" Ring										X		X	X
23	**29139	Nozzle, Main	X	X	X	X	X	X	X	X	X	X	X	X	X
24	27113	Spring, Choke stop	X	X		X	X			X		X			
25	29155	Repair Kit (Incl. items marked *)	X	X	X	X	X	X	X		X	X	X	X	X
25	29157	Repair Kit (Incl. items marked *)								X					

** Whenever main nozzle is removed, it must be replaced by service main nozzle. Cross drilled holes in original nozzle cannot be lined up properly once it is removed.

Figure 68

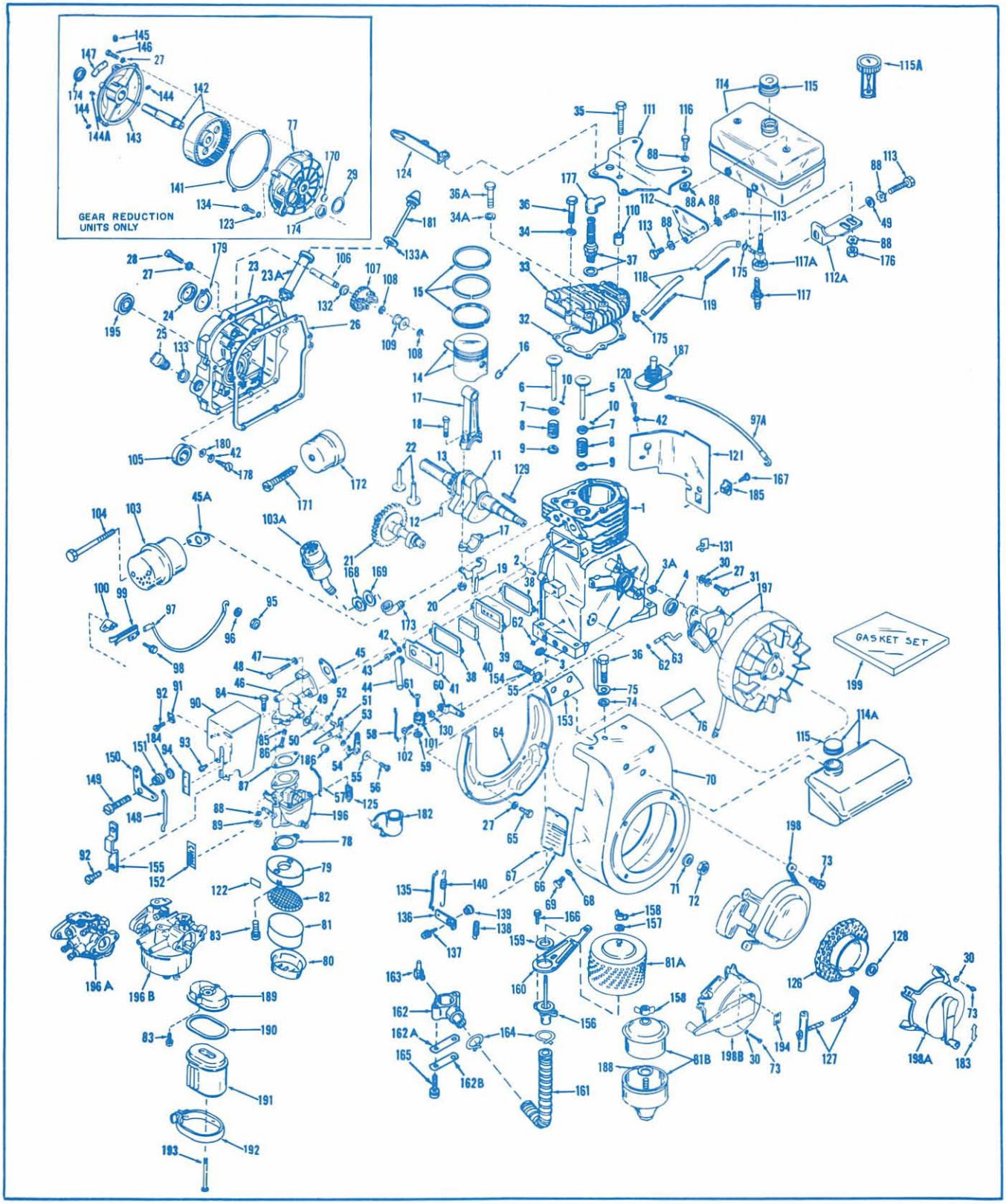

Figure 69

Suppose we decided this engine has carburetor Number 196B. We would then go to the section in the parts list under carburetors and find it under this number. Figure 70 shows an exploded view drawing of this carburetor.

We'll go into more detail on parts identification later in the course. At this time we are only getting familiar with exploded view drawings since they will be used quite extensively in further lessons in the course.

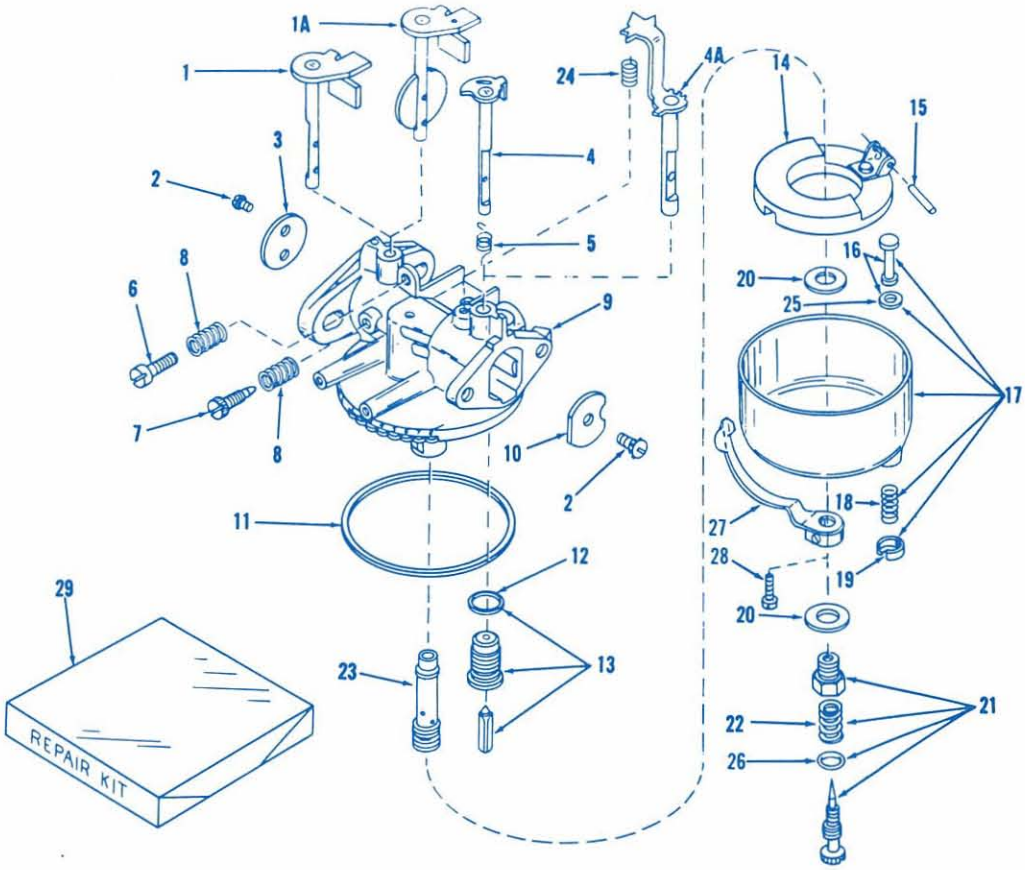

Figure 70

FLOAT CARBURETOR REPAIR

There are about fifteen to twenty different things that should be checked on each float carburetor. Figure 71 shows the different parts that are most likely to cause carburetion trouble in addition to the air passage system we covered earlier. Cleaning of air passages is a must and should be done with compressed air if possible every time the carburetor is worked on. The design of carburetors varies so much that it is impossible to give specific instructions for each and every model. There are enough similarities in the basic design that we can cover the general area of repair.

Before beginning repair of any carburetor it is best to always clean it thoroughly in a good solvent and blow it dry with air. After the carburetor has been cleaned you can begin the disassembly. Inspect each part as it is being disassembled for wear and damage.

The high speed needle valve shown at A in Figure 71 should be inspected for wear around the tapered point end. This valve fits into the main nozzle shown at R. This needle valve can easily be damaged by turning it into the main nozzle too tight. If it is rough or has ridges around the tapered part it should always be replaced. Generally, this valve is replaced as an assembly including the valve, spring and "O" ring.

The "O" ring shown at B should also be checked for dryness, cracks or breaks. This ring is fitted on the needle and recessed in a slot. A bad "O" ring at this point can cause a fuel leak. The washers or gaskets shown at C and E should also be inspected for breakage, wear or excessive hardness. One of these washers goes inside the fuel bowl and the other goes on the outside. Wear or excessive hardness or cracks can cause fuel leakage from the bowl. The parts shown at D are the fuel drain assembly and are replaced as an assembly. If the rubber gasket shows wear or damage it would be well to replace this assembly even though it were not leaking at the time of disassembly.

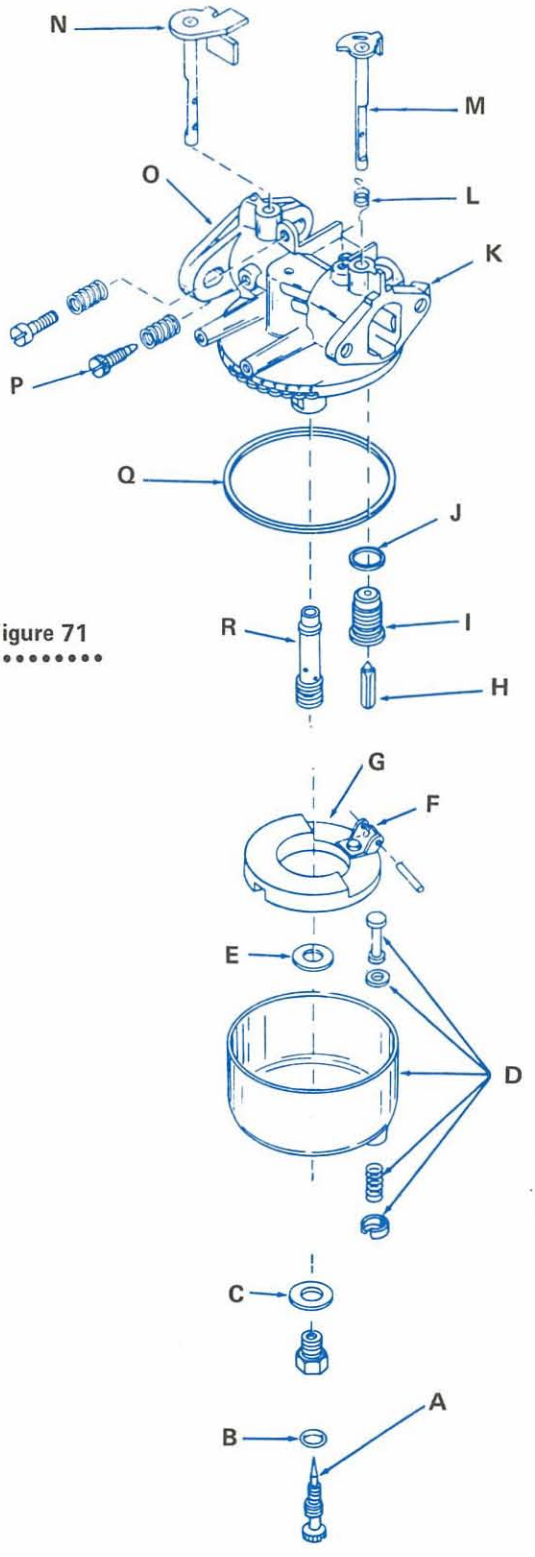

Figure 71

Remove the float shown at G and check the condition. This may be either a cork float or a metal float. To remove the float you first pull the pin from the float hinge. Check the float for mechanical condition and wear. Be sure the metal float does not have fuel in it. A metal float can develop small leaks and allow fuel to enter. When you remove the float and can feel fuel inside, it will be necessary to replace the float with a new one. Sometimes they can be soldered, however, it is a good practice to replace with a new float. If it is bent or shows any damage it should be replaced with a new one.

Some floats are made of cork and coated with varnish to keep them from absorbing gasoline. If the coating shows signs of cracking or damage it should be replaced.

Next inspect the needle valve shown at H. This valve should be checked for operation before the float has been removed and after it has been reinstalled. When the carburetor is held with the float down, the float should be able to be lifted up and down easily and the needle valve shown at H should come down when the float drops. The needle valve should not hang up. If this needle valve does not work freely you should pull the hinge pin and remove the float. The trouble could be in either the seat shown at I or the gasket shown at J. These parts are generally replaced as an assembly.

There is a gasket between the inlet part of the carburetor at K and the air filter. If this gasket is worn or cracked it will allow unfiltered air to enter the carburetor. The spring shown at L controls the choke lever shown at M. If this spring is weak, disconnected or not functioning properly it will prevent the shaft from opening and closing the choke shutter properly.

Check the choke lever for side play. Too much wear between the choke shaft and the carburetor housing will permit excess air to enter and cause problems with the air balance of the choke and fuel.

The throttle shaft shown at N should be checked the same as the choke shaft. Sometimes these are seated in bushings between the carburetor housing and the shaft, but most of them are not. Excessive wear, causing a sloppy fit on either or both of the shafts, will generally require a new carburetor housing and shafts.

There is another gasket shown at O between the carburetor and the manifold or engine side of the carburetor. If this gasket is worn it will allow excess air to enter the engine with the fuel-air mixture coming from the carburetor. This will cause a lean running mixture and make the engine run erratic.

The low-speed adjustment needle shown at P should be checked the same as the high speed needle for wear and replacement made if necessary. The gasket shown at Q seals between the body of the carburetor and the fuel bowl. If this gasket is worn or damaged it will allow fuel to leak.

The main fuel nozzle shown at R seats with the high speed adjustment needle shown at A. This can be removed for inspection but generally is not necessary unless there is severe damage to the adjustment needle A. If this needle shows damage from over-tightening, it would be a good idea to remove the main discharge nozzle for inspection. Check to be sure the proper size screwdriver is used to remove this nozzle.

As a general rule, on this type carburetor, if the gaskets are in good shape, the air passages are clean and the float works freely, you will have a carburetor capable of functioning properly after it has been adjusted.

This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

(Fold Here)

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EXAMINATION ON LESSON 8
DRAWINGS, PART NUMBERS AND FLOAT CARBURETOR REPAIR

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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The throttle valve changes the mixture of the fuel and air going into the engine. ____ ____
   TRUE
   FALSE

2. Parts, such as the number 17 bowl assembly, are not sold seperately. ____ ____
   TRUE
   FALSE

3. Parts marked with an asterisk (*) indicate that they are used in more than one place. ____ ____
   TRUE
   FALSE

4. If a fuel mixture has too much air it is referred to as _____. ____ ____
   a. lean mixture
   b. rich mixture
   c. neither of the above

5. In an exploded view drawing all of the component parts are shown in relationship to the _____ part of the assembly. ____ ____
   a. chassis
   b. main
   c. main lever

6. The same part number may be used for more than one part as long as it looks similiar. ____
   TRUE
   FALSE

(Continued on page 2)

7. Fig 8-1 shows the carburetor parts that can be used with different model carburetors. Fill in the carburetor model number the following parts can be used with.

28636/shaft and lever assembly — 28626, 28627
28653/body assembly
28236/shaft and lever assembly
29169/body assembly
*28945/needle assembly

CARBURETOR NUMBERS
28234, 28249, 28302, 28382, 28415, 28626, 28627, 28815, 28860, 28922, 28959, 29168, 29237

REF. NO.	PART NO.	PART NAME	CARB. NOS.	28234	28249	28302	28382	28415	28626	28627	28815	28860	28922	28959	29168	29237
1	28236	Shaft & Lever Assy., Throttle		X				X								
1A	28871	Shaft & Lever Assy., Throttle			X						X	X	X	X		
1A	27551	Shaft & Lever Assy., Throttle				X	X									
1B	28636	Shaft & Lever Assy., Throttle							(X)	(X)						
1C	29171	Shaft & Lever Assy., Throttle													X	X
2	630606	Screw, Sems, 4-40 x 3/16		X	X	X	X	X	X	X	X	X	X	X	X	X
3	27553	Shutter, Throttle		X	X	X	X	X	X	X	X	X	X	X	X	X
4	27135	Shaft & Lever Assy., Choke		X	X		X	X			X					
4	28923	Shaft & Lever Assy., Choke											X			
4A	27778	Shaft & Lever Assy., Choke				X						X		X		
4B	28637	Shaft & Lever Assy., Choke							X	X					X	X
5	27787	Spring, Choke return.				X			X	X		X		X	X	X
6	630605	Screw, Throttle adjustment		X	X	X	X	X	X	X	X	X	X	X	X	X
7	*27112	Needle, Idle		X	X	X	X	X	X	X	X	X	X	X	X	X
8	27114	Spring, Adjustment needle		X	X	X	X	X	X	X	X	X	X	X	X	X
9	28235	Body Assy., Carburetor.		X												
9	28880	Body Assy., Carburetor.			X											
9	28653	Body Assy., Carburetor.				X				X		X				
9	28464	Body Assy., Carburetor.					X				X		X			
9	28477	Body Assy., Carburetor.						X								
9	28642	Body Assy., Carburetor.							X							
9	28962	Body Assy., Carburetor.												X		
9	29169	Body Assy., Carburetor.													X	
9	29238	Body Assy., Carburetor.														X
10	27541	Shutter, Choke		X	X		X	X			X					
10	27786	Shutter, Choke				X			X	X		X		X		
10	28924	Shutter, Choke											X		X	X
11	*27109	Gasket, Bowl-to-body		X	X	X	X	X	X	X	X	X	X	X	X	X
12	27108	Gasket, Seat		X	X	X	X	X	X	X	X	X	X	X	X	X
13	*29154	Valve, Seat & Gasket Assy. (Incl. No. 12)		X	X	X	X	X	X	X		X	X	X	X	X
13	*29156	Valve, Seat & Gasket Assy. (Incl. No. 12)									X					
14	27105	Float		X	X	X	X	X	X	X	X	X	X	X	X	X
15	*27106	Shaft, Float		X	X	X	X	X	X	X	X	X	X	X	X	X
16	27136	Stem Assy., Bowl drain		X	X	X	X	X	X	X	X	X	X	X	X	X
17	27101	Bowl Assy. (Incl. Nos. 16, 18 & 19)		X	X	X	X	X	X	X	X	X	X	X		
17	29170	Bowl Assy. (Incl. Nos. 16, 18 & 19)													X	X
18	27137	Spring, Bowl drain		X	X	X	X	X	X	X	X	X	X	X	X	X
19	27138	Retainer, Bowl drain stem		X	X	X	X	X	X	X	X	X	X	X	X	X
20	*27110	Gasket, Bowl-to-body		X	X	X	X	X	X	X	X	X	X	X	X	X
21	*27111	Needle Assy., Power adjusting (Incl. No. 20)		X	X	X	X	X	X	X	X	X		X		
21	*28945	Needle Assy., Power adjusting (Incl. No. 22)											X		X	X
22	*27544	"O" Ring											X		X	X
23	**29139	Nozzle, Main		X	X	X	X	X	X	X	X	X	X	X	X	X
24	27113	Spring, Choke stop		X	X		X	X			X		X			
25	29155	Repair Kit (Incl. items marked *)		X	X	X	X	X	X	X		X	X	X	X	X
25	29157	Repair Kit (Incl. items marked *)									X					

** Whenever main nozzle is removed, it must be replaced by service main nozzle. Cross drilled holes in original nozzle cannot be lined up properly once it is removed.

Figure 8-1

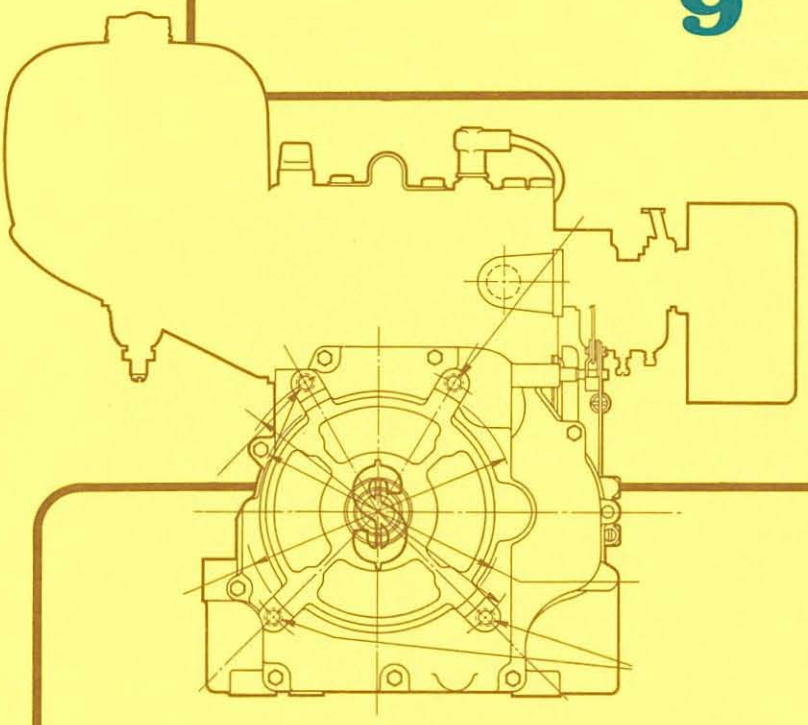
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

9



TURN THIS PAGE

...and let's find out all about --

DIAPHRAGM, SUCTION LIFT AND AUTOMAGIC CARBURETORS

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DIAPHRAGM CARBURETOR

The diaphragm carburetor uses a spring-loaded diaphragm to transfer fuel to the carburetor. A diaphragm is actually a flexible part or wall that separates two cavities. This flexible portion is held rigid around the outside edge but it is flexible enough to pulsate back and forth, due to difference in pressure on either side.

A diaphragm serves the same purpose as the float in the float carburetor. The use of a diaphragm does not depend on a float controlled fuel bowl and can be operated in most any position. The float carburetor will only operate in an upright position for any sustained length of time.

This feature makes the diaphragm carburetor very adaptable to many engines, such as chain saws, that are often operated in different positions. They are also used on many other types of small engines. This type carburetor is especially adaptable to 2-cycle engines since they provide for activating the diaphragm from the low pressure area in the crankcase.

Figure 72 shows the basic operating principles of a diaphragm. A low or high pressure area on either side of the diaphragm will cause it to flex in either direction. Point A shows how the diaphragm will flex when a high pressure area is present above the diaphragm. In this condition the hole shown at A-1 is closed. This hole is in the cover plate.

The diaphragm is located between this cover plate and the carburetor body. When a low pressure area is created above the diaphragm as shown in B it changes position as shown. When it flexes up as shown, there is an opening at B-1 which allows air to enter at atmospheric pressure.

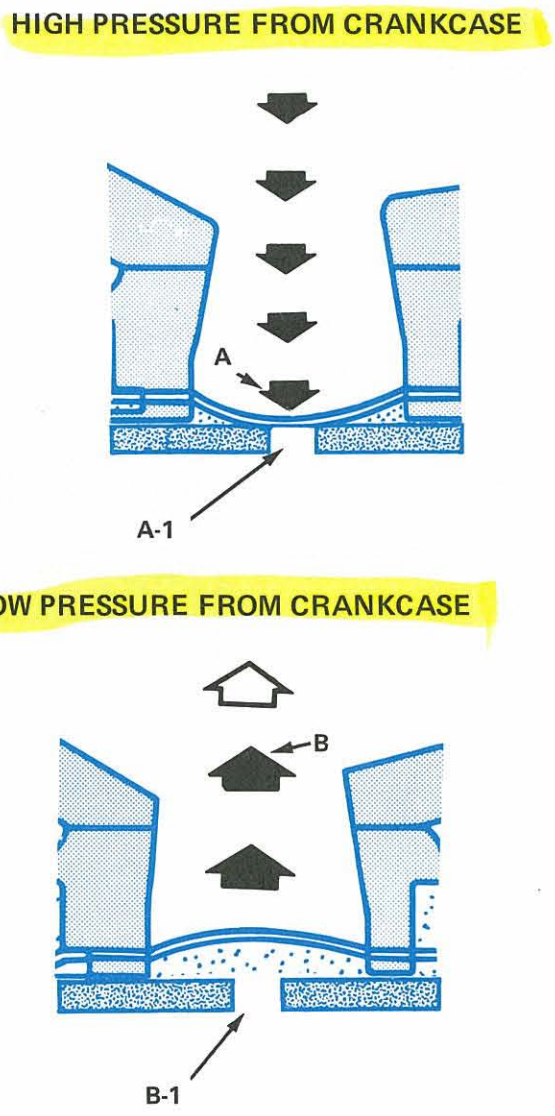

Figure 72

Figure 73 shows how the diaphragm works in conjunction with the engine. As the piston moves down a low pressure area is created in the venturi area of the carburetor as shown at A-1. The atmospheric pressure shown at A-2 forces the diaphragm up because there is a low pressure area on top and a high pressure area, which would be the atmospheric pressure of the air, on the bottom. When the diaphragm raises it opens the fuel valve shown at A-3. Fuel will then enter the diaphragm chamber just above the diaphragm.

The drawing in Figure 73 shows the fuel valve working from a pivot shown at A-4. Many carburetors have different methods of opening and closing this valve but they accomplish the same purpose. With the diaphragm in this condition fuel is being brought into the carburetor from the fuel supply. The fuel then goes directly to the venturi section of the carburetor as shown at A-1.

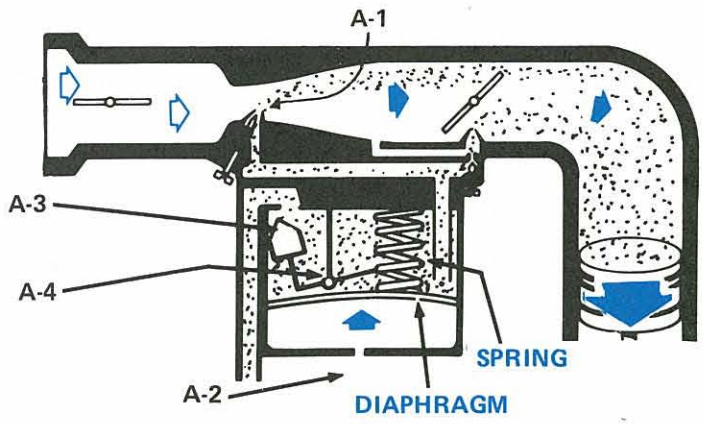

Figure 73

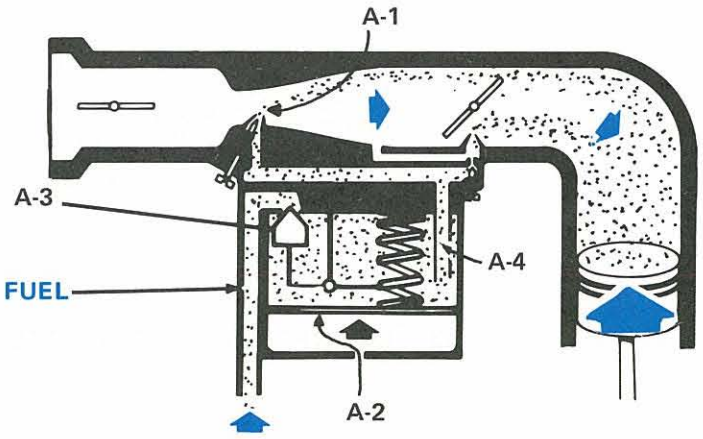

Figure 74

When the piston moves in the opposite direction as shown in Figure 74, there is no longer a low-pressure area in the venturi as shown at A-1. The diaphragm at A-2 then closes the fuel valve as shown at A-3. The diaphragm chamber and the fuel passage-ways shown at A-4 remain full of fuel ready for the next intake stroke of the piston. All of this happens very rapidly, several thousand times a minute, making a constant supply of fuel always available to the engine.

DIAPHRAGM CARBURETOR REPAIR

Repair of float and diaphragm carburetors are very similar. If you compare the carburetor body shown in Figure 75 with the float carburetor shown in Figure 70 you will notice many similarities. Both have throttle and choke shafts along with low and high speed valve adjustments that serve the same basic function. The choke lever shown at A and the throttle shaft shown at B should receive the same inspection. There are also gaskets at C and C-1 that should be inspected and replaced if necessary. The idle adjustment at D and the throttle adjustment valve at E should also be inspected.

After inspecting these parts of the carburetor you can remove the diaphragm assembly. First remove the screws, shown at F, holding the cover to the carburetor body. Directly under the cover you'll find the diaphragm shown at G. Inspect it carefully for any wear or damage. The least amount of wear of this part will warrant replacement. There is a gasket shown at H, however, you will not always find this since some carburetors are designed so the diaphragm serves the purpose of this gasket.

After the diaphragm assembly has been removed all the air passages should be blown out with air and the carburetor cleaned. The needle valve and seat assembly shown at J should be inspected and replaced if they show wear or damage. This is generally replaced as an assembly. If the needle works freely up and down it is generally in good shape.

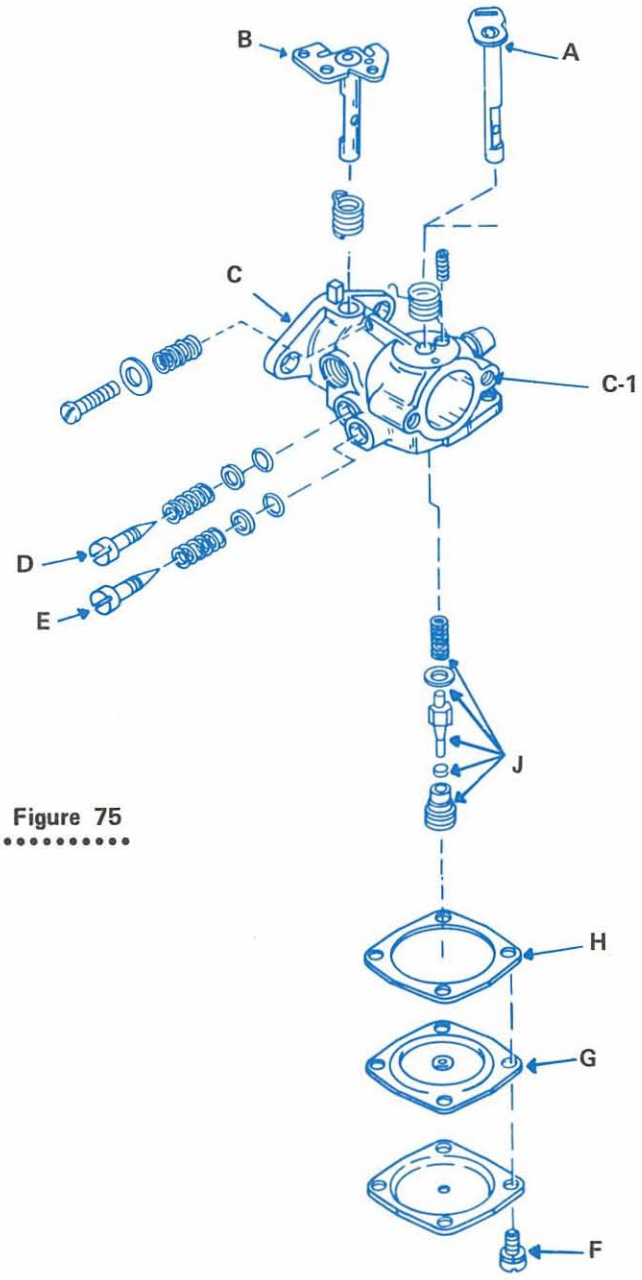

Figure 75

SUCTION LIFT CARBURETOR

The suction lift carburetor is usually mounted on top of the fuel tank and draws its fuel directly from the tank. This type carburetor is not very popular any more. It was formerly used on many inexpensive engines. Like the diaphragm, this carburetor is also dependent on the vacuum or low pressure area of the engine for operation.

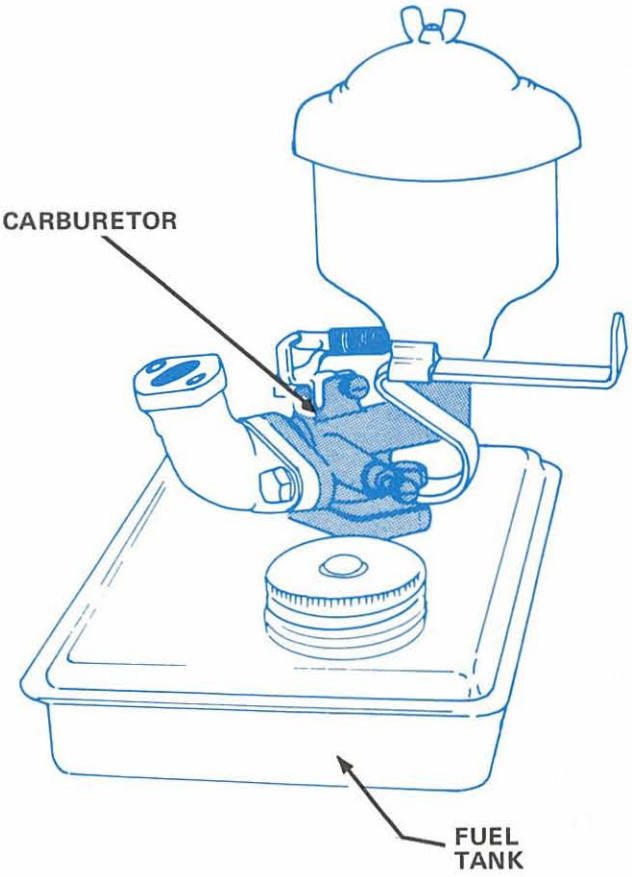

Figure 76

Figure 76 shows a typical suction lift carburetor installed on the fuel tank. These are used primarily on 4-cycle engines. Vacuum from the engine intake stroke on 4-cycle engines causes a low-pressure area in the venturi section of the carburetor. This would be on the down stroke of the piston on 4-cycle engines.

Figure 77 shows the basic principles of this carburetor when used with a 4-cycle engine. As the piston goes down, it creates low pressure in the venturi shown at A-1. Since the atmospheric pressure is lower at this point than the pressure on the fuel at A-2, fuel is forced by this pressure out of the fuel supply and up into the venturi, and then to the engine.

Horsepower is limited on engines using this type of carburetor because the suction lift is limited. The fuel supply to the carburetor will vary with the amount of fuel in the tank. Seldom do engines over 3 horsepower use this type of carburetor.

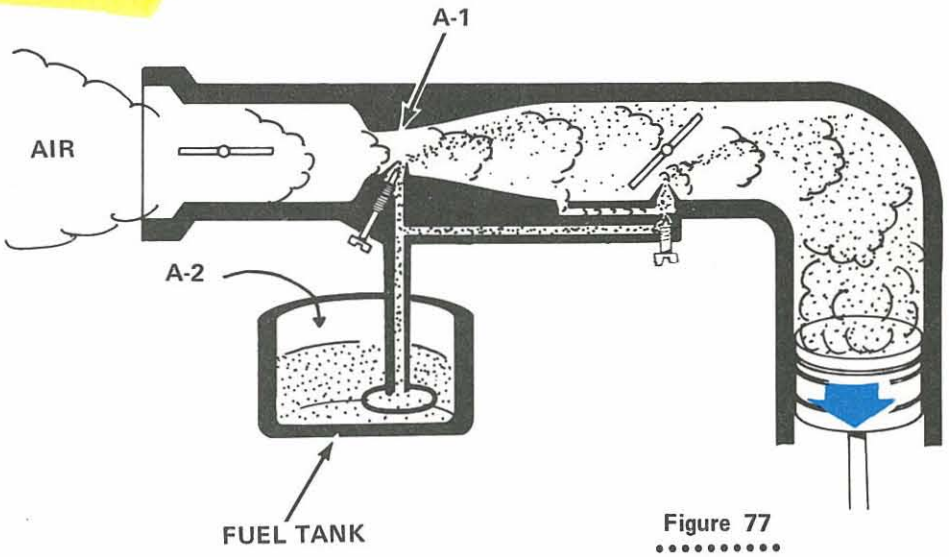

Figure 77

Many suction lift carburetors are designed so that choking, running and stopping the engine is accomplished with only one control valve. Figure 78 shows the position of the control valve for starting the engine. The valve is closed and the piston creates a vacuum as it moves down. This causes a rich fuel mixture to enter the engine. As we mentioned earlier, this type of carburetor is generally limited to smaller horsepower engines but, with the addition of a fuel pump, it can be used on larger engines. The fuel pump lifts fuel from the regular fuel supply to an auxiliary fuel reservoir. Most engines are now made with different types of carburetors since these are becoming almost obsolete. Figure 79 shows the control valve set in the running position. The control valve, shown at A, is in the open position. This allows fuel to be drawn from the tank into the carburetor and on into the engine. In order to stop the engine, the control valve is moved into the position shown in Figure 80. This stops all fuel coming from the tank and stops the engine.

ENGINE CHOKED FOR STARTING

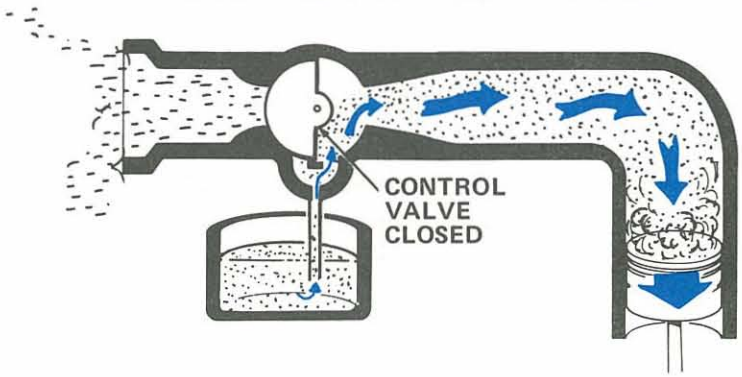

Figure 78

ENGINE RUNNING

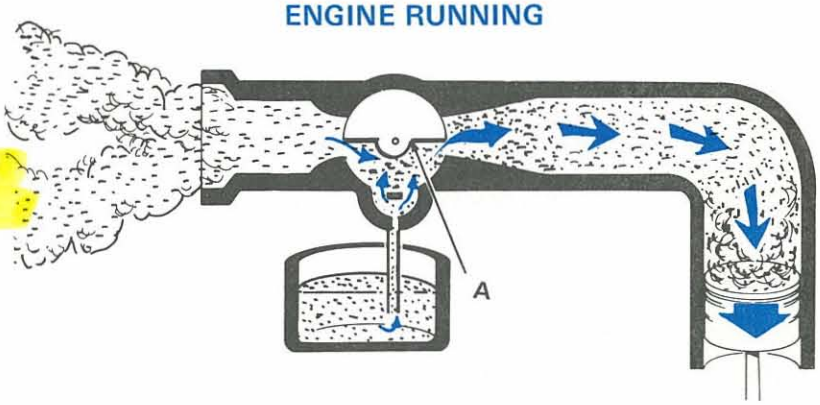

Figure 79

ENGINE STOPPED

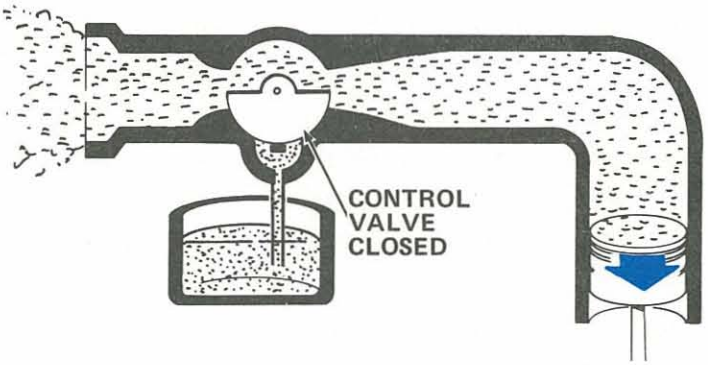

Figure 80

SUCTION LIFT CARBURETOR REPAIR

Many of these suction lift carburetors have no means of adjusting the fuel mixture. Some of them may have a high speed adjustment but no idle mixture adjustment. Service and repair of these carburetors is generally limited to cleaning and inspecting the unit and replacing any necessary parts. First remove the carburetor from the fuel tank and inspect and clean the fuel line, filter, and screen that extends down into the tank. Check the control valve for wear and clean the carburetor body. Replace all gaskets that show wear.

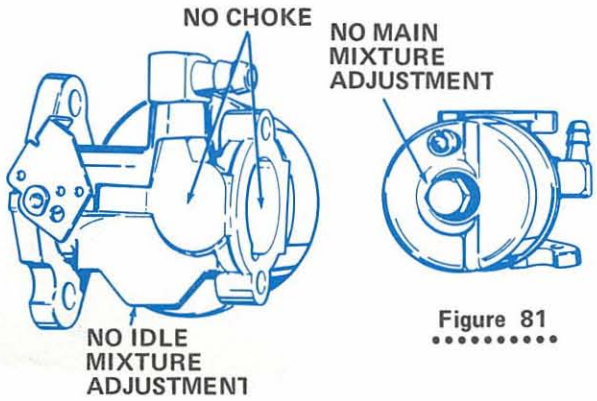

Figure 81

AUTOMAGIC CARBURETOR

Figure 81 shows the basic difference between the regular float carburetor and the Automagic carburetor. The Automagic float carburetor is almost identical in appearance and some working functions as most other type carburetors. If you will compare the exploded view drawing in Figure 82 with the float carburetor, shown in Figure 71, you will notice they are quite similar in appearance, except the Automagic carburetor, shown in Figure 82, does not have either a high-speed or low-speed idle adjusting screw or choke. It has only a throttle adjustment. Everything else is automatic.

This type carburetor is comparatively new in the small engine design and has possibilities of becoming quite popular. One nice feature is that it practically eliminates the engine operator or other inexperienced people from tampering with the adjustment. Adjustment by inexperienced people is one of the major causes of much engine trouble. To operate an engine with an Automagic carburetor the only step necessary is to move the control lever from the off position so the butterfly valve will be in the open position to allow fuel to enter the venturi. The fact that this carburetor does not have speed adjustment valves and choke does not mean it is trouble-free. The only service problems that have been eliminated are the speed adjustments.

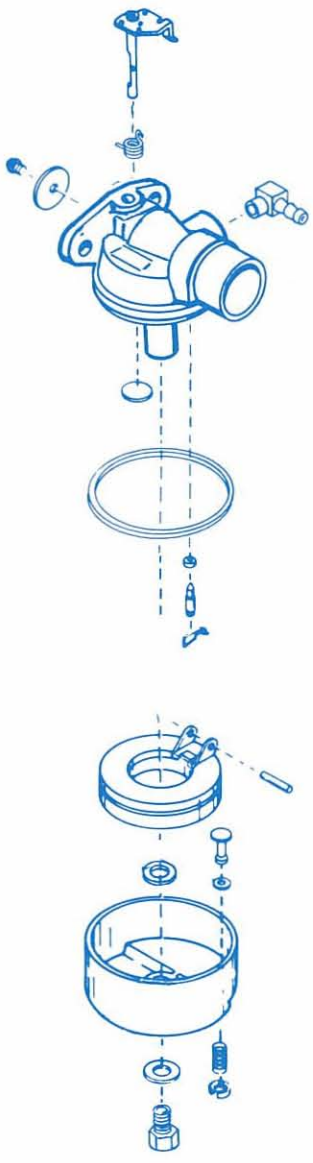

Figure 82

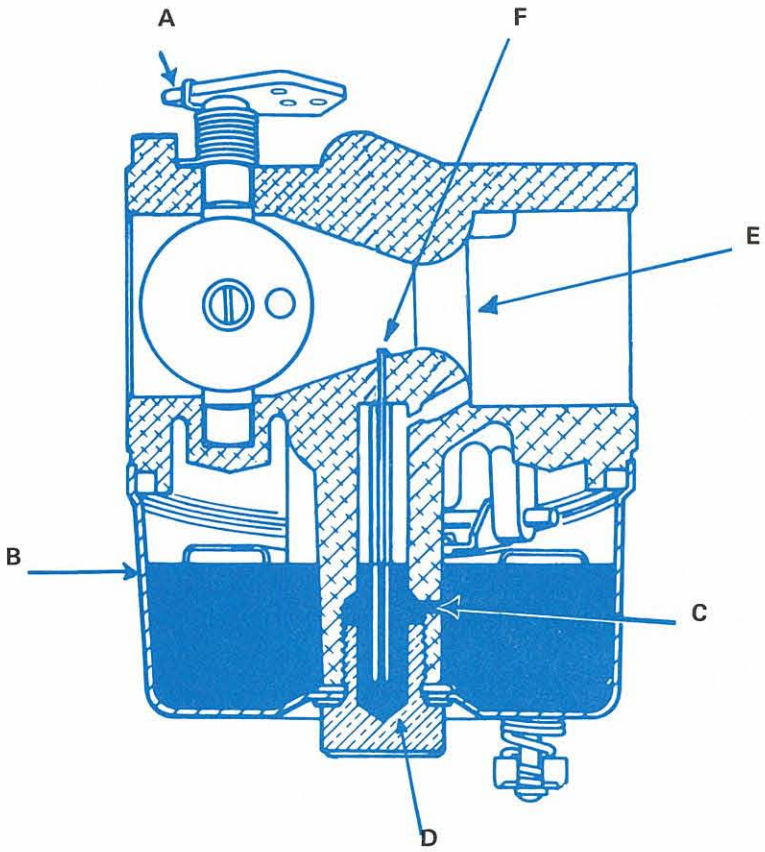

Figure 83

Figure 83 shows a cross section view of this carburetor. The throttle control lever, which is the only fuel control to this carburetor, is located at point A. The float and fuel level is shown at B. The fuel level in the bowl is maintained by the float, the same as other float carburetors. When the engine is not running fuel enters at the main jet, shown at C. It then fills the prime well shown at D, for starting.

The throttle is in the open position for starting as shown at A. When the engine is cranked for starting, the piston creates a low pressure area in the venturi, shown at E. This low pressure area causes fuel to be drawn up through the main nozzle at F. When fuel is drawn into the venturi of the carburetor it empties the prime well. This gives a rich mixture of fuel for starting.

Figure 84 shows fuel entering the venturi at A. So far we have strictly fuel going into the venturi and combustion chamber. In order for the engine to operate it is necessary to have air mixed with this fuel. There is an air bleed hole shown at B, however, it cannot become effective and supply air until the fuel in the prime well is pushed into the main nozzle. This means the engine is started almost on straight fuel. This is the same as choking the engine and is one of the basic principles of the design of this carburetor.

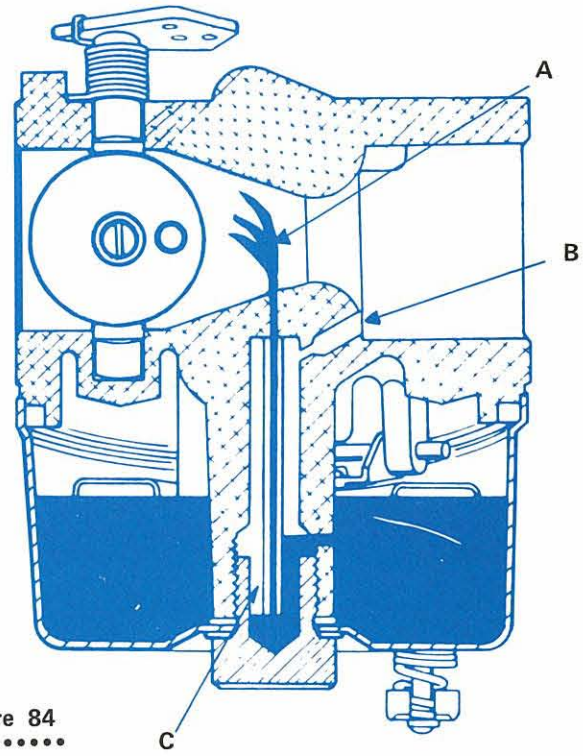

Figure 84

As the engine begins to run, the fuel level stabilizes in the lower end of the main nozzle, as shown at C. When this happens, air from the air bleed at B is allowed to mix with the fuel. This causes the combustible mixture necessary for running. The fuel air mixture is basically controlled by the size of the hole from the float chamber to the well. The diameter of this hole is very critical. If it is too large, it will allow an excess of fuel to mix with the air. This causes a rich mixture. If the hole is too small or restricted by foreign matter, it will not allow adequate fuel and will cause the mixture to be too lean.

There is no running adjustment for this carburetor other than the governor control speed which will be covered when we get into the operation of the governor.

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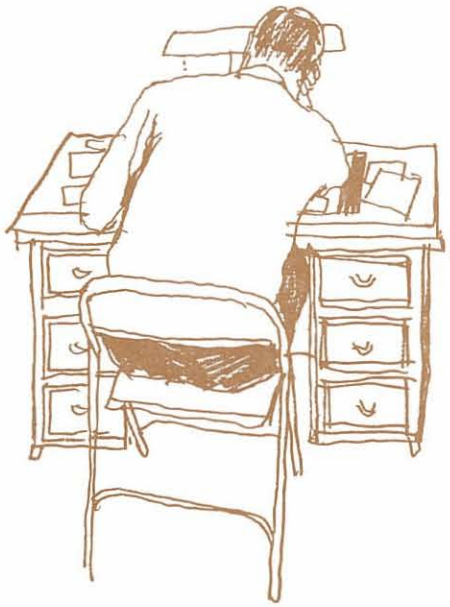

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Before returning your completed Exam, Remember.....

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- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
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2. Fill in your Student Number at top left corner of this sheet.
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EXAMINATION ON LESSON 9
DIAPHRAGM, SUCTION LIFT AND AUTOMAGIC CARBURETORS

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(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The same reference number may be used several times in the same parts drawing. ____
   TRUE
   FALSE

2. The diaphragm carburetor can only be used with two cycle engines that operate in an upright position. ____
   TRUE
   FALSE

3. Point B in Fig. 9-1A shows a _____ pressure area. ____
   a. low pressure
   b. high presure
   c. neither of the above

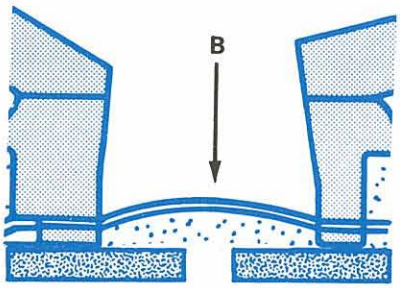

Figure 9-1a

(Continued on page 2)

4. Fill in the letters showing the part of the typical diaphragm carburetor shown in Fig. 9-2.
   choke lever
   needle valve and seat assembly
   idle adjustment screw
   diaphragm
   throttle shaft

5. Point A in Fig. 9-3 shows a high pressure area.
   TRUE
   FALSE

6. Identify the condition of the engine with the control valve set in the position shown in Fig. 9-1.
   engine stopped
   engine running
   engine choked

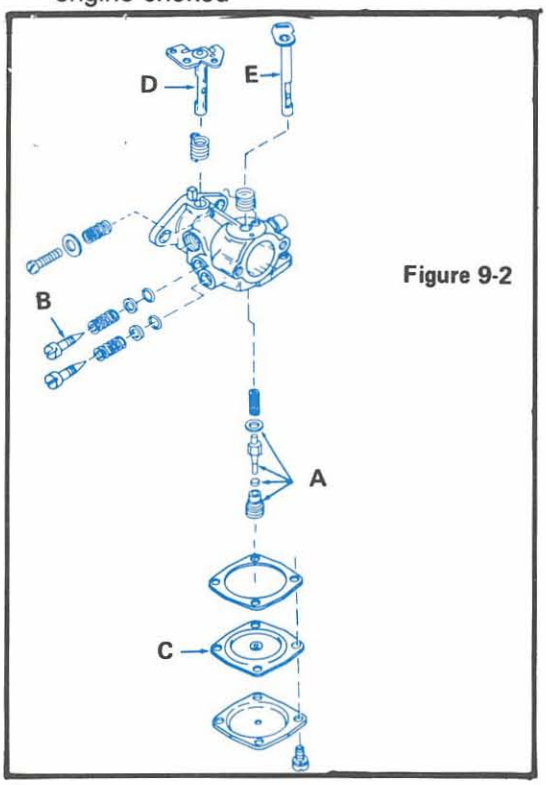

Figure 9-2

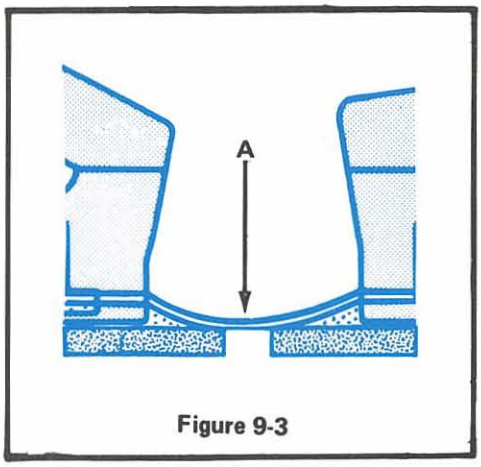

Figure 9-3

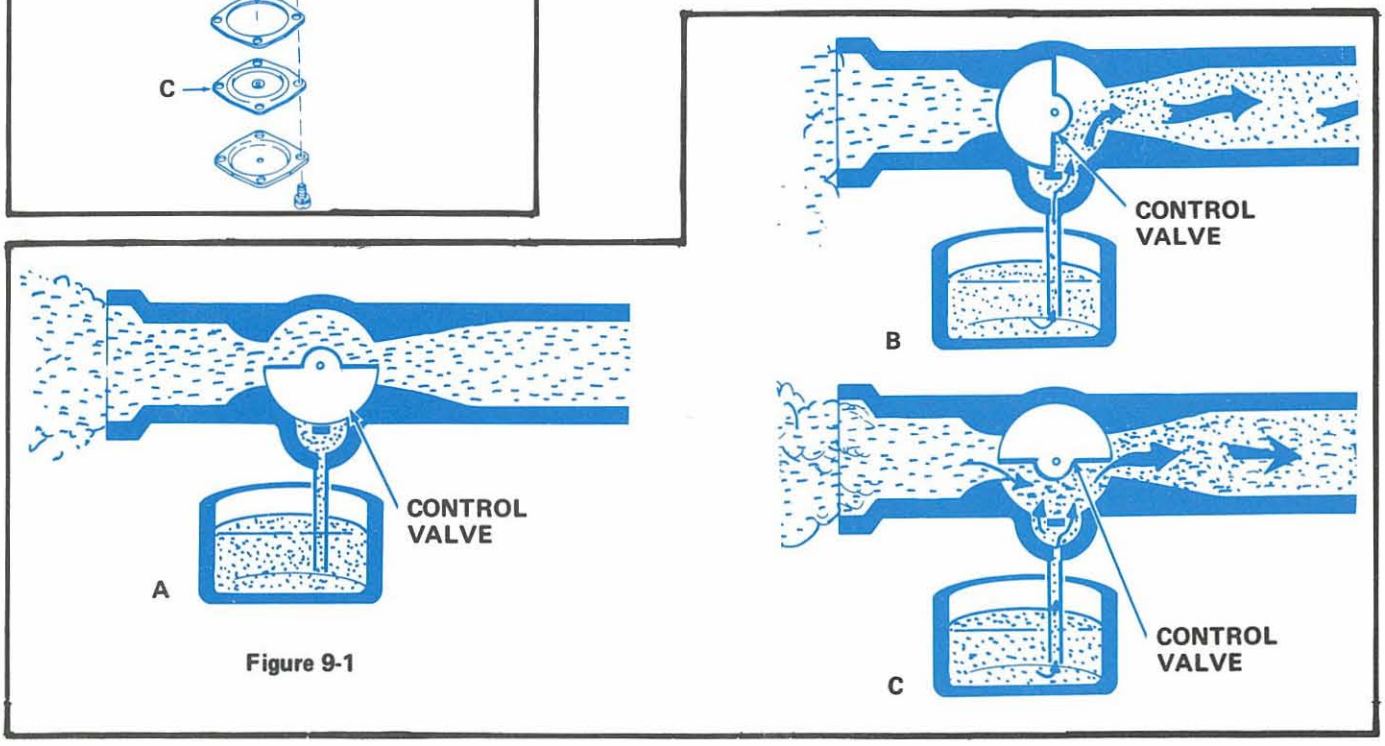

Figure 9-1

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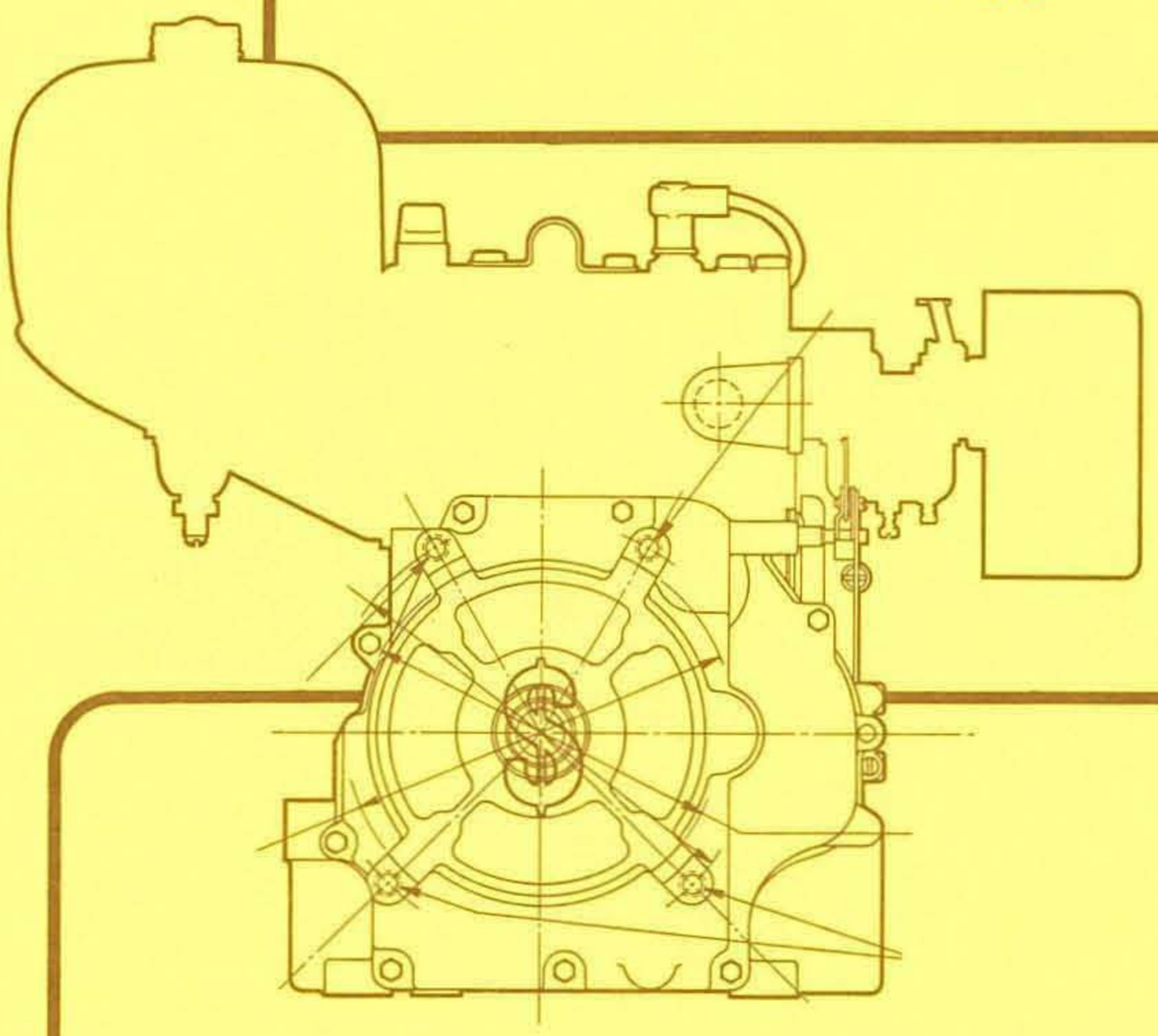

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CARBURETOR LINKAGE

Before removing the carburetor it is a good idea to make a sketch of the linkage connections. After you become more familiar with carburetors you will remember how these linkages are attached. It is absolutely necessary to reinstall the carburetor linkages correct to assure a properly running engine.

Figure 85 shows a view of a throttle control and the governor arm. Both of these pivot at point A. Notice there are three holes in both the throttle and governor arm. Sometimes there may be more or less holes. These holes are used to connect the linkage between the throttle and governor so the governor can control the throttle when engaged.

Often there are two sets of linkages between the throttle and the governor. One set will go direct to the manual throttle to set the governor in the proper position for starting the engine. The other goes from the throttle to the governor to control the engine when it is ready for full operation. This second manual throttle control is shown at point B.

Before removing the carburetor make a sketch as shown in Figure 86. Just draw a line connecting both the throttle and the governor arm showing the location of the spring shown at A and the arm shown at B. Be sure to make this sketch so these linkages are reinstalled in the same holes.

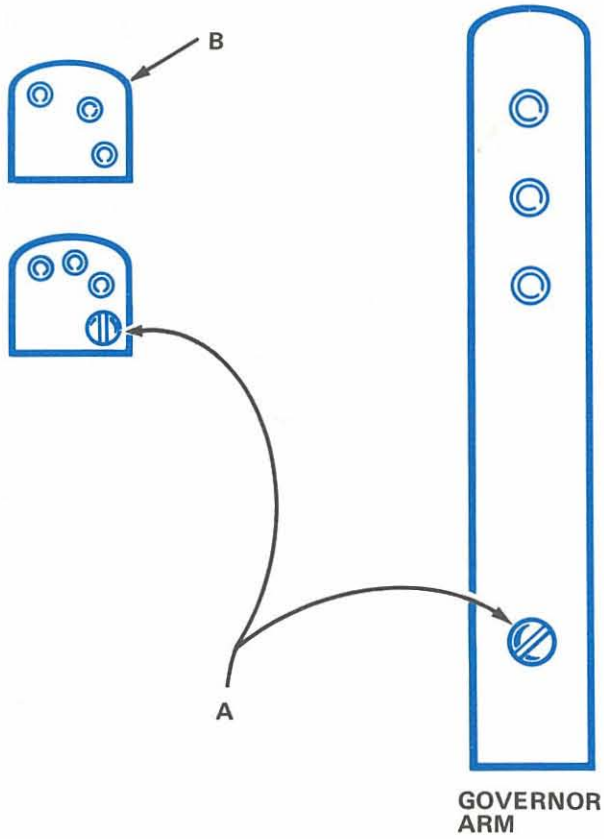


Figure 85

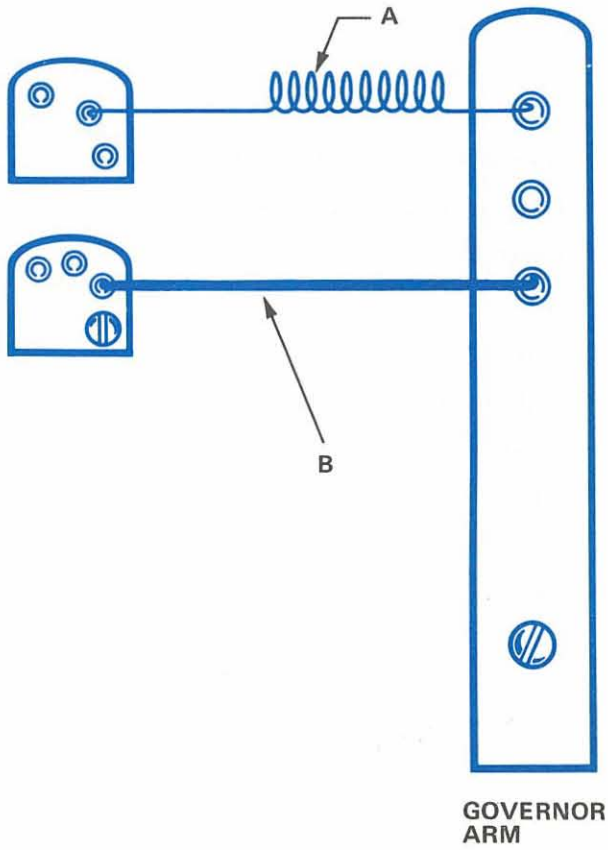


Figure 86

CLEANING CARBURETORS

Dirty carburetors are probably one of the biggest sources of trouble that occur in small engines. The air and fuel passages in these carburetors are very small and can easily become clogged with foreign matter that is almost always present in any fuel.

Carburetor cleaning is generally the first step in any small engine repair job. Gasoline is not recommended as a cleaning fluid because of the danger of explosion. The ferrous metals accidently scraping together can cause a spark and ignite gasoline. The recommended cleaning fluid is kerosene, mineral spirits or diesel fuel. These fluids are not nearly as explosive as gasoline and will do an equally good job of cleaning.

The first step is to remove the entire carburetor from the engine. Before removing the linkage controlling the throttle, choke and governor it is best to study them carefully so they can be reinstalled the same way.

After the carburetor is removed, first clean the entire unit by soaking it in one of the cleaning solvents. Use a small paint brush to clean all the outside surfaces. Next remove the fuel bowl if it is a float type carburetor and clean and inspect for any worn or bad parts. Remove the cover plate on a diaphragm carburetor, clean and inspect the diaphragm for wear. Next remove the idle adjustment valve. Soak the entire unit in cleaning solvent and then blow dry with compressed air if available. Each air fuel passage should be blown out with air to be sure it is free of foreign matter before reassemblying.

INSTALLING THE CARBURETOR

Install the gasket between the carburetor and the engine. Check this gasket to be sure it is not cracked or too badly compressed. This gasket very often has to be replaced because it is exposed to the extreme heat of the engine and is under pressure. It is very important since a worn or leaky gasket will allow air to enter between the carburetor and the engine. This causes the fuel mixture to be too lean.

In many cases it is easier to connect some of the control linkages and fuel line before bolting the carburetor to the engine. Connect the governor linkage and hand throttle adjustments.

One important point to remember is to connect the ignition ground wire if it is attached to the carburetor. Often this wire is attached to the carburetor with a spring clip. The last to install is the air filter.

CARBURETOR ADJUSTMENTS

Before the carburetor can be adjusted all other repair and maintenance on the engine must be completed, including the electrical system which we will cover later. Everything has to be in balance. A carburetor in perfect adjustment and operating condition will not run a smooth engine if other areas need repair or adjustment. The carburetor and the air filter have to be cleaned and installed before any adjustments are attempted. On most carburetors there are three adjustments necessary. They are the high and low speed mixture adjustments and the idle speed adjustment. Figure 87 shows these adjustments for a typical float carburetor. After checking the fuel and all throttle linkage controls you should check to be sure the fuel vent cap is free of foreign matter. You should be able to blow through it easily.

Turn the idle mixture adjustment, shown at A, clockwise all the way in. It is best to turn this in by hand to avoid over tightening. Then back the adjusting screw out one full turn. Do the same with the high speed adjustment shown at B. Turn the idle adjustment screw at C in about one-half turn. As a general rule, most carburetors have the idle mixture adjustment on the engine side of the carburetor. This may not always be true but, in many cases, it will be located on the engine side.

If all other linkages are connected and the fuel line is attached you can crank the engine. It might be necessary to choke it through one or two cranks and then release the choke. Run the engine up to operating speed and adjust the high speed adjustment screw first. Turn the adjustment screw in, clockwise about 1/8 turn and listen to the engine. You should be able to hear an increase or decrease in the engine speed. If there is no noticeable difference continue turning the high speed adjustment screw in, until you can hear some difference in the engine speed. It should go either up or down.

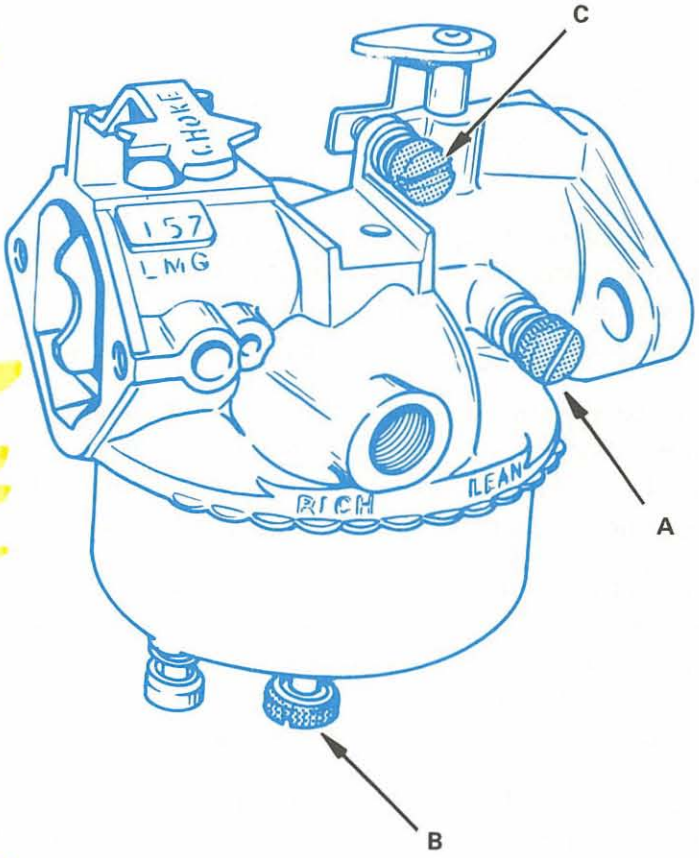


Figure 87

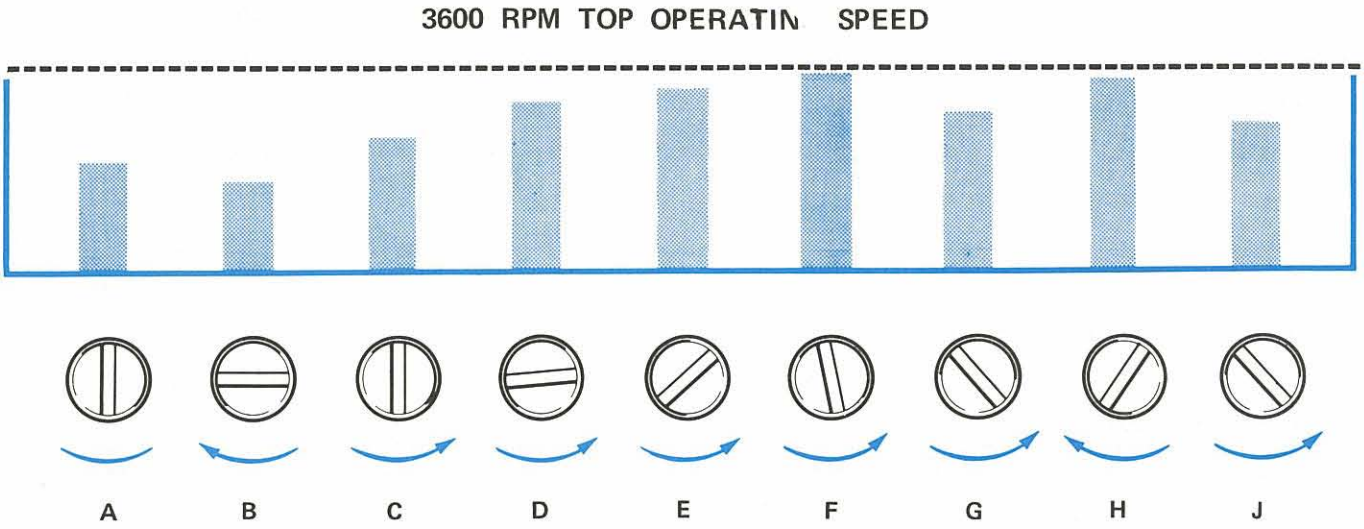


Figure 88

Figure 88 shows the steps in adjusting either the high speed or low speed mixture adjustment. The carburetor could possibly be set on the proper adjustment, but this would not be very likely. In any event, turning the high speed adjustment in or out will cause the engine to either speed up or slow down.

Set the engine at high operating speed. Suppose the adjusting screw is positioned as shown at A. By listening to the speed of the engine you determine that it is not operating at full capacity. If you turn the adjustment in about 1/4 turn, as shown at B, the engine will very possibly slow down. Since you started with only one full turn out on the adjustment the mixture, very possibly, is too lean.

Turn the adjustment about 1/4 turn out, counterclockwise, and the engine speed should pick up. Continue turning slowly counterclockwise as shown at C, D, E and F. The engine speed continues to increase as you turn the adjustment screw counterclockwise. You will finally reach a point where the mixture will begin to get too rich and the engine will begin to slow down.

Notice at G, the engine begins to slow down. Turn the adjustment back the other direction as shown and the engine should begin to pick up speed again, as shown at H. Always test several times at this point to be sure you have reached maximum engine speed. If you turn the adjustment counterclockwise again, as shown at J, the engine should begin to slow down. Do this several times until you are sure the engine is operating at maximum speed, as shown at F and H.

After you have the high speed adjustment complete, slow the engine down to idle speed. Next, make the idle speed adjustment the same way. After you have the idle speed adjusted, you can then set the idle speed control adjustment screw, as shown in Figure 87. This adjustment is only for setting the speed of the engine when it is not operated under load. The idle speed adjustment is for the fuel and air mixture, the same as the high speed adjustment. Some carburetors have no idle mixture adjustment. The mixture is regulated by the size of the discharge port or hole. It is part of the carburetor design. Others, such as the Automagic carburetor that we studied earlier, have neither high or low speed adjustments. They are taken care of in the carburetor design.

CHOKE ADJUSTMENT

Adjustment of the choke valve is usually limited to the adjustment of the choke linkage between the control handle or the carburetor and control valve. First remove the air cleaner and check the operation of the choke valve as it is being opened and closed. It should operate free.

Notice the position of the valve after closing the choke control. The valve should be completely closed. If it is not, you can adjust the linkage.

Figure 89 shows the choke linkage connected to the carburetor. Loosen the adjusting set screw, then close the valve with your finger, and hold it shut while retightening the set screw.

Open the choke valve with the control and check the valve. It should be all the way open. If it is not all the way open, recheck the stop opening. Make sure all linkage works free. Sometimes the control wire inside the cable will become rusty and tend to freeze. This will make the control wire hard to work. The entire cable can be soaked in kerosene for a few minutes and it will work this rust free.

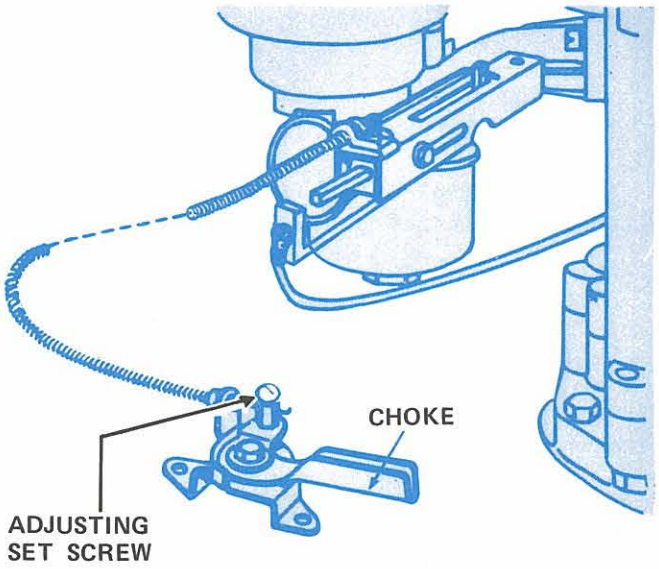
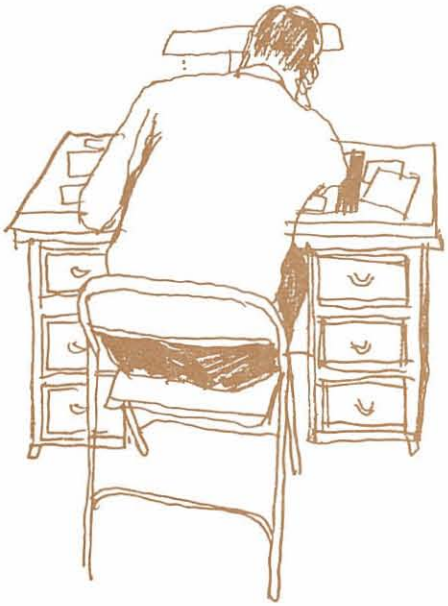


Figure 89



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EXAMINATION ON LESSON 10
CARBURETOR CLEANING AND ADJUSTMENTS

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(3) Be sure to follow the instructions on the Homework Assignment Sheet.

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ANSWER

1. The _____ speed adjustment screw is to control the engine speed when it is not under load. ____
   a. idle
   b. high speed
   c. low speed

2. On most carburetors there are four adjustments. ____
   TRUE
   FALSE

3. When the governor is engaged it controls the throttle speed. ____
   TRUE
   FALSE

4. Oxygen must be present with fuel to make it combustible. ____
   TRUE
   FALSE

5. The carburetor should be adjusted with the air filter in place. ____
   TRUE
   FALSE

6. A defective gasket between the carburetor and the engine will cause the fuel mixture to be too _____. ____
   a. rich
   b. lean
   c. neither of the above

7. An individual part with the same part number may fit more than one engine model. ____
   TRUE
   FALSE

8. The three adjustments necessary for most carburetors are high speed, low speed, and idle. ____
   TRUE
   FALSE

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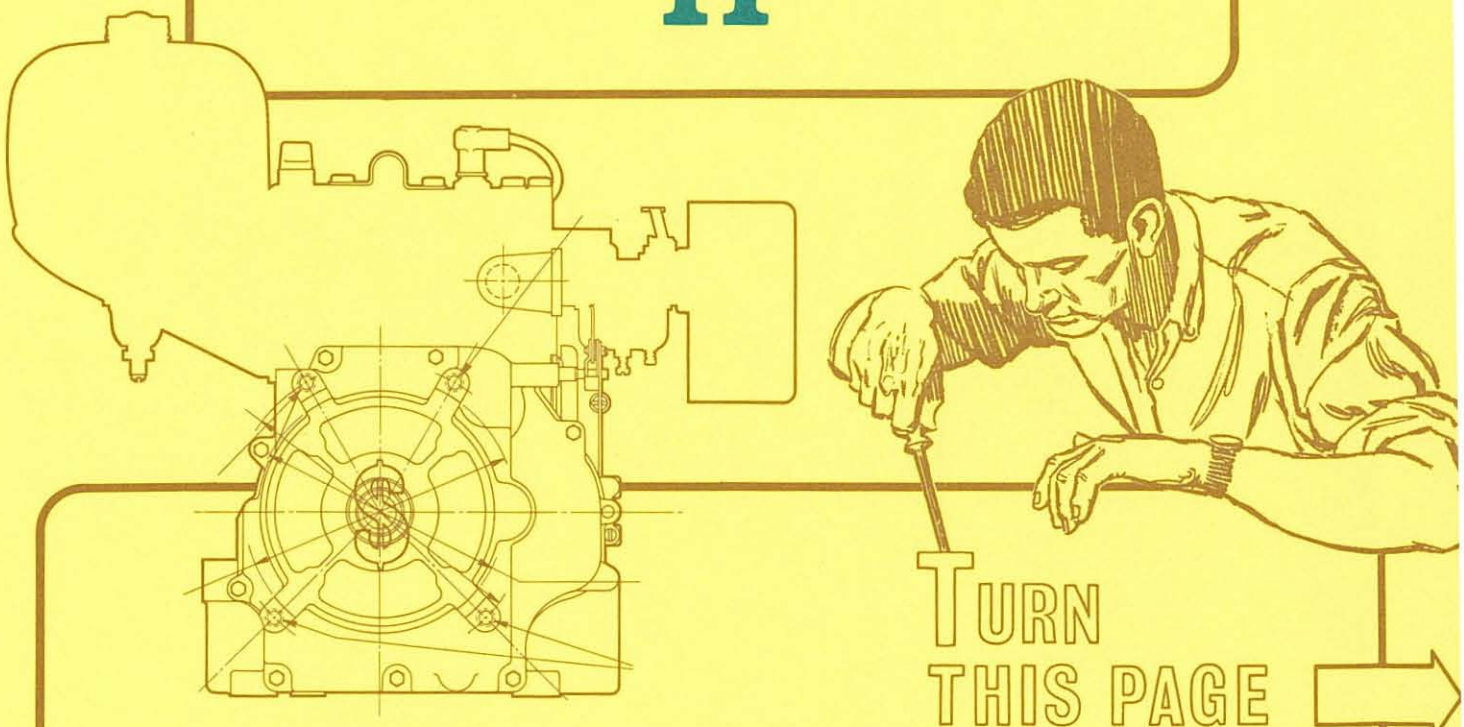

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...and let's find out all about --

TWO AND FOUR CYCLE FUEL

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FUEL

The grade, mixture and quality of fuel used in small engines is very important for proper operation. Gasoline is a form of chemical energy that can be mixed with air and converted into mechanical energy. Gasoline without air will not burn or explode. In the absence of air, a lighted match can be extinguished by dipping it in raw gasoline and not cause a fire.

Vapor caused from the mixture of air and fuel will burn. A petroleum product will not burn when in a liquid state without air. Gasoline will vaporize rapidly. The principle of vaporization is shown in Figure 90. The presence of heat increases vaporization. If heat is applied to fuel, as shown at A, it will create a vapor when mixed with air as shown at B. This mixture causes combustion, not the raw fuel.

Gasoline can become stale. It deteriorates with age. This is one common cause of small engine failure. Often the owner will have fuel left over from the previous year when he starts to use his lawnmower or outboard motor and will use it the first time he uses the machine. It is not at all uncommon for owners to leave fuel in their engines from one year to the next. When fuel becomes old it forms gum and other residues that will coat the internal parts of the engine. This causes excess wear on the engine and, in general, it will not perform as well as it does with fresh fuel. This old fuel will cause a rapid build-up of deposits of carbon, varnish and sludge.

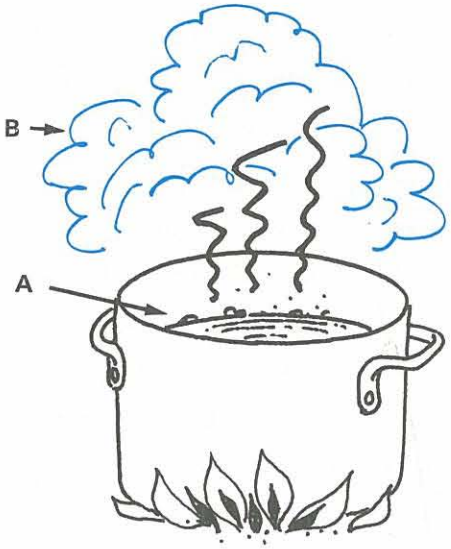


Figure 90

All fuel should be drained from an engine if it is to be stored for any length of time or not operated. Fuel left over at the end of the season should never be used later as engine fuel.

OCTANE RATING

The octane rating of fuel is a method of comparing the anti-knock qualities of a fuel used in a spark ignition engine. This knock is caused by a detonation that occurs when the fuel burns unevenly. This occurs when only part of the fuel charge in the combustion chamber is ignited by the spark plug. The unburned part of the fuel mixture becomes compressed in the cylinder until its temperature reaches the point of self ignition. This is actually a second explosion or ignition of the fuel mixture. They do not occur at the same time and this causes a knocking noise. It is actually a hammering force on the piston, instead of a uniform pushing force.

The octane rating should be matched to the engine design. Engineers recommend the octane specifications to be used in the engines they design. Different types of engines are designed to operate on different octane ratings. The octane rating recommended for most small engines is in the area of 90 to 95 octane. This is commonly known as regular gasoline.

So-called high test and other premium gasolines are not recommended for small engines. Fuel ratings and mixtures are generally given in the Operator's Manual for the particular engine and on the name plate.

Using the wrong octane fuel will cause the engine to lose power and can even cause serious damage to the piston and rings. The engine will operate at a higher temperature when exposed to this double explosion caused by the wrong octane rating for the engine design. Prolonged operation at higher temperature can also cause burning of the valves.

SUMMER AND WINTER FUELS

In recent years fuels have been developed to better fit the climatic conditions in which they will be used. This provides for easier starting. In the summer, oil companies now blend their fuel so the volatility is low. The volatility of a fuel is its tendency to evaporate. Different liquids and particularly fuels have different degrees at which they will evaporate rapidly.

A heavy petroleum like oil has a very low tendency to evaporate. An open can of oil can sit for a long period of time and show practically no loss from evaporation. On the other hand, an open can of gasoline, sitting in a warm area, will evaporate so rapidly you can actually see the fumes or vapor rising above it. If summer gasoline is used after the weather turns cold, the engine will generally be hard to start because the gasoline has lower volatility. In the winter, gasoline is blended so it has a higher-degree of volatility. This makes the engine easier to start.

If you use winter gasoline after the weather gets warm there will be considerably more loss from evaporation. Gasoline varies so much by temperature that oil companies buy and sell gasoline not only by the gallon but by temperature.

STORING FUEL

The only control the operator or the engine repair shop has over the volatility of the fuel is to buy it in small quantities and keep it stored properly. Proper storage not only reduces evaporation but also decreases the chances of moisture becoming absorbed with the gasoline. Besides providing fresh gasoline it is very important that it be clean. Fuel used in these small engines must pass through some very fine openings and the smallest particle of foreign matter can clog any one of them.

Figure 91 shows a fuel container that is considered one of the best for storing fuel for small engines. This can has a vent and filter spout that contains a screen filter to prevent foreign matter from getting into the storage tank.

Different states and cities have laws regarding the storage and use of fuels. You should be familiar with the laws in your area as they could affect your insurance. In the small engine service shop there is always the presence of fuel and this creates a danger of fire if not cared for properly.

Figure 91

Actually gasoline is very safe to work with if you know its principles and how to handle it in a safe manner. Carelessness is the biggest cause of accidents resulting from gasoline becoming ignited.

Gasoline stored in small containers will begin to form gums and varnishes after being stored only two or three months. It will do the same thing when stored this long in the fuel tank. This foreign matter will cause clogged carburetor jets, foul the spark plugs, damage the pistons, rings and valves.

Some gasolines break down faster than others when in storage. Their life depends much on the kind of additives, length of time in storage before purchasing and the type of storage. To be on the safe side, the engine operator and the engine repair shop should purchase fuel only in small quantities and from a reliable dealer who has a large enough turnover in his tanks to be assured of fresh gasoline.

CAUTION

Never use or store gasoline in a closed area without adequate ventilation. A basement area is particularly dangerous for the storing and use of gasoline. Generally there is a natural gas-fired hot water tank or furnace in these areas with a pilot light. Gasoline fumes from open fuel containers will collect along the ceiling area and eventually reach the open flame.

2-CYCLE FUEL

All 2-cycle engines require a mixture of oil with the fuel. This is only for 2-cycle engines. Four-cycle engines operate on straight fuel with a separate oil supply. Two-cycle engines are lubricated from the oil contained in the fuel. Always use clean, fresh regular gasoline, not Ethyl or other premium type fuels, mixed with a good grade of non-detergent crankcase oil. SAE-30 is considered satisfactory for almost all small engines. Some manufacturers do not recommend using multi-viscosity oils. Viscosity means a resistance to the tendency to flow. Some kinds of oil now on the market are made so they have multi-purpose use in both cold and warm weather.

These are sometimes referred to as 10W-30W, which means they are designed to operate in a wider range of temperatures and engine conditions. They can be used in 4-cycle engines with separate oil supply. A good grade of SAE 30 or 40 is considered adequate as long as it is detergent oil.

The fuel and oil mixture for 2-cycle engines should be from 1/2 to 1/4 pint of oil to each gallon of gasoline. Generally most small engine repair shops use a standard of 3/8 pint for each gallon of gasoline.

The addition of more oil than recommended will cause poor combustion and the formation of gum, varnishes and carbon deposits in the engine. The exhaust ports will become clogged, the engine will lose power and, in general, not function properly.

The oil mixture in 2-cycle engines is very critical since this is the only form of lubrication this engine has. If the mixture is too lean it will cause excess wear on all engine parts and it will eventually freeze.

Fuel for 2-cycle engines should not be mixed in the fuel tank. This is one very common fault of many operators. They pour in the proper amount of oil and gasoline and think it will be mixed and ready for use. Since both are petroleum products it would appear they would mix easily. This is not true. They do not mix easily but after they are mixed they do not separate. For this reason it is very important that the proper amount of oil and gasoline be mixed and stored in a separate tank.

You should have an adequate size enclosed tank for mixing and the container should have more capacity than the amount of fuel you intend to mix. Make sure the storage tank is clean of all foreign matter and moisture. Fill the container 1/2 to 3/4 full of gasoline. When doing this it is always a good idea to strain the gasoline through a fine filter. Add the oil to the gasoline. Do not add the gasoline to the oil. An even better way is to fill the tank only about 1/4 full of gasoline, add the oil and shake the container so it will begin to mix. Then add the balance of the gasoline and mix by shaking the container.

Always keep 2-cycle fuel containers marked showing the fuel is for 2-cycle engines. You should always have two separate containers of fuel in the shop for servicing both 2-cycle and 4-cycle engines and it is very easy to get them mixed up.

CAUTION

Never fill either a 2 or 4-cycle engine tank while the engine is running. Always wipe off dust and any gasoline that may have spilled on the engine. Before replacing the cap on the gas tank be sure the vent hole is free of any foreign matter and allows air to pass through.

FUEL DELIVERY SYSTEM

The fuel system probably causes more trouble than any other system of the internal combustion engine. Most troubles in the fuel system are minor and easily corrected but they can sometimes be tricky in detecting just where the trouble exists.

Very often, fuel trouble starts with the operator because he does not open the fuel valve or attempts to start the engine without fuel.

The primary function of the fuel tank is to provide a ready source of fuel near the engine. The size of the tank is generally decided by the size of the engine and the application it is used for.

Lawnmowers generally have a tank holding just a little over a quart. This is usually all that is necessary to mow the average lawn. If this same engine were used for operating a pump that was required to run several hours at a time it would be engineered with a larger fuel tank. The shape and location of the fuel tank will vary according to the design of the equipment the engine is to be used with. Tanks are made of steel, nylon, plastic and other materials. Rust is always a problem with most of the metal tanks.

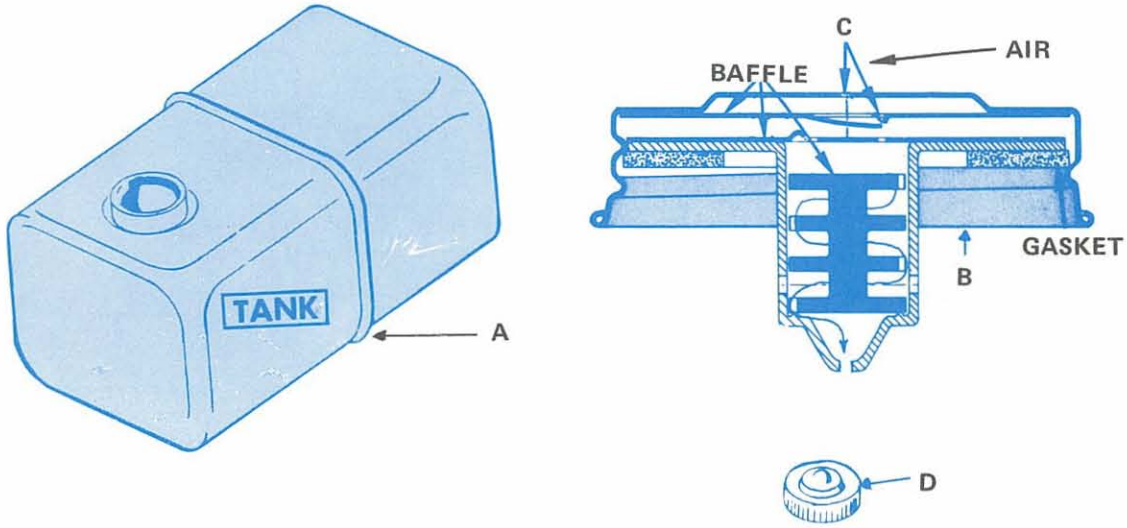


Figure 92

One very important feature of all systems is the vent system. Every tank must have some vent system to provide atmospheric pressure to equalize the pressure in the tank and the outside air pressure. Figure 92 shows a typical tank and vented cap. The tank, shown at A, should be inspected carefully each time an engine is serviced. Metal tanks will accumulate rust and scale along with other foreign matter. This will eventually work its way into the carburetor.

Tanks made of material other than metal will not cause the rust accumulation problem but they will pick up foreign matter through the fuel supply. Tanks should always be cleaned inside and out each time an engine is serviced.

The fuel cap, shown at B, is a much more important part of the system than most people think. It is not simply a cover to keep fuel from spilling out of the tank. This cap must have a vent system so it can let air into the tank and, at the same time, keep out as much foreign matter as possible. If the vent in the cap is not kept open when the engine is operating a vacuum will develop in the tank.

There are various designs in fuel tank caps to permit air to enter the tank. The one shown at B uses a valve operated by the vacuum created in the tank. As a vacuum is developed in the tank, a valve or vent, as shown at C is opened and allows air to enter the tank. If the tank is tilted or turned upside down the pressure of the fuel against this valve closes it. This prevents fuel from leaking out through the vent.

Some caps are of a much more simple design like the one shown at D. There is a small hole in the top of the cap with a gasket inside the cap that also has holes in it. This permits air to enter the tank. Others have a small screw or valve in the top that can be opened when the engine is in use to allow air to enter. The screw can be closed when the engine is stored.

Gas tanks on chain saws and other engine applications that require operation in other than level position have a flexible fuel pick-up hose, as shown in Figure 93(a). There is a weight on the pick-up hose shown at A. This weight moves around as the engine changes position so it is always at the bottom or lowest part of the tank and in the fuel. Often there is a fuel strainer on this end of the pick-up line.

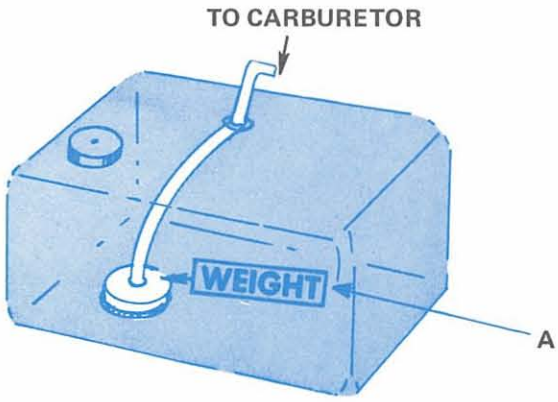


Figure 93(a)

Figure 93(b)

Many engines are equipped with a combination fuel strainer, shut-off valve and sediment bowl as shown at B. This is one of the best methods of delivering fuel to the carburetor that is free of foreign matter. Water, being heavier than gasoline, settles to the bottom of the sediment bowl along with other foreign matter. It is easily visible through the glass bowl and will remind the operator to clean it.

Many pressure feed and gravity feed tanks have a strainer at the bottom as shown at C. Sometimes this strainer will be part of the shut-off valve. Some tanks are equipped with a gauge as shown at D. Some have a float type gauge that will show a direct reading. Others are a simple dip stick type gauge.

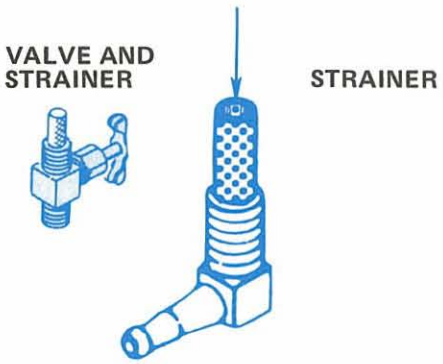


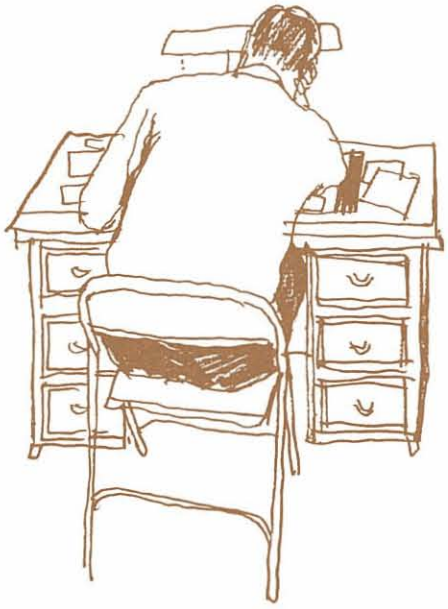
Figure 93(c)

Figure 93(d)

Repairing of fuel tanks is limited to steel or other metal tanks, except aluminum. Steel tanks can be soldered but no attempt to solder them should be made until they have been cleaned and dried. It is not practical to attempt repairing tanks of other materials since they can generally be replaced at less than the labor cost.

CAUTION

Never apply heat to a fuel tank that has gas fumes inside. They will explode.



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EXAMINATION ON LESSON 11
TWO AND FOUR CYCLE FUEL

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(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. In the winter, gasoline is blended so it has a higher-degree of volatility. _____
   TRUE
   FALSE

2. The fuel knock in small engines is caused by a detonation that occurs when fuel burns unevenly. _____
   TRUE
   FALSE

3. If the vent in the fuel tank cap is not kept open when the engine is running, a vacuum will develop in the tank. _____
   TRUE
   FALSE

4. A fuel/oil mixture will separate after they have been stored for more than two months. _____
   TRUE
   FALSE

5. Gasoline is a form of chemical energy that can be converted into mechanical energy when mixed with air. _____
   TRUE
   FALSE

6. The oil mixture in a two cycle engine is very critical since this is the only form of lubrication the engine has. _____
   TRUE
   FALSE

7. The volatility of fuel is its tendency to evaporate. _____
   TRUE
   FALSE

8. Rust is always a problem with most plastic fuel tanks. _____
   TRUE
   FALSE

9. Vapor caused from the mixture of fuel and air will burn. _____
   TRUE
   FALSE

(Continued on page 2)

10. The fuel mix for a two cycle engine should always be mixed in the fuel tank. _____
    TRUE
    FALSE

11. A high octane rating fuel is recommended for most small engines. _____
    TRUE
    FALSE

12. Every fuel tank must have some vent system to allow atmospheric pressure to equalize the pressure in the tank. _____
    TRUE
    FALSE

13. The viscosity of oil means the resistance to the tendency to flow. _____
    TRUE
    FALSE

14. The fuel tank on a small engine should always be left full when left in storage or off season. _____
    TRUE
    FALSE

15. Cold fuel will evaporate faster than warm fuel. _____
    TRUE
    FALSE

16. The fuel and oil mixture for most two cycle engines should be from ½ to ¼ pint of oil for each 2 gallons of fuel. _____
    TRUE
    FALSE

17. Gasoline can be stored indefinitely. _____
    TRUE
    FALSE

18. The presence of heat increases vaporization. _____
    TRUE
    FALSE

19. All four cycle engines operated on straight fuel with a separate oil supply. _____
    TRUE
    FALSE

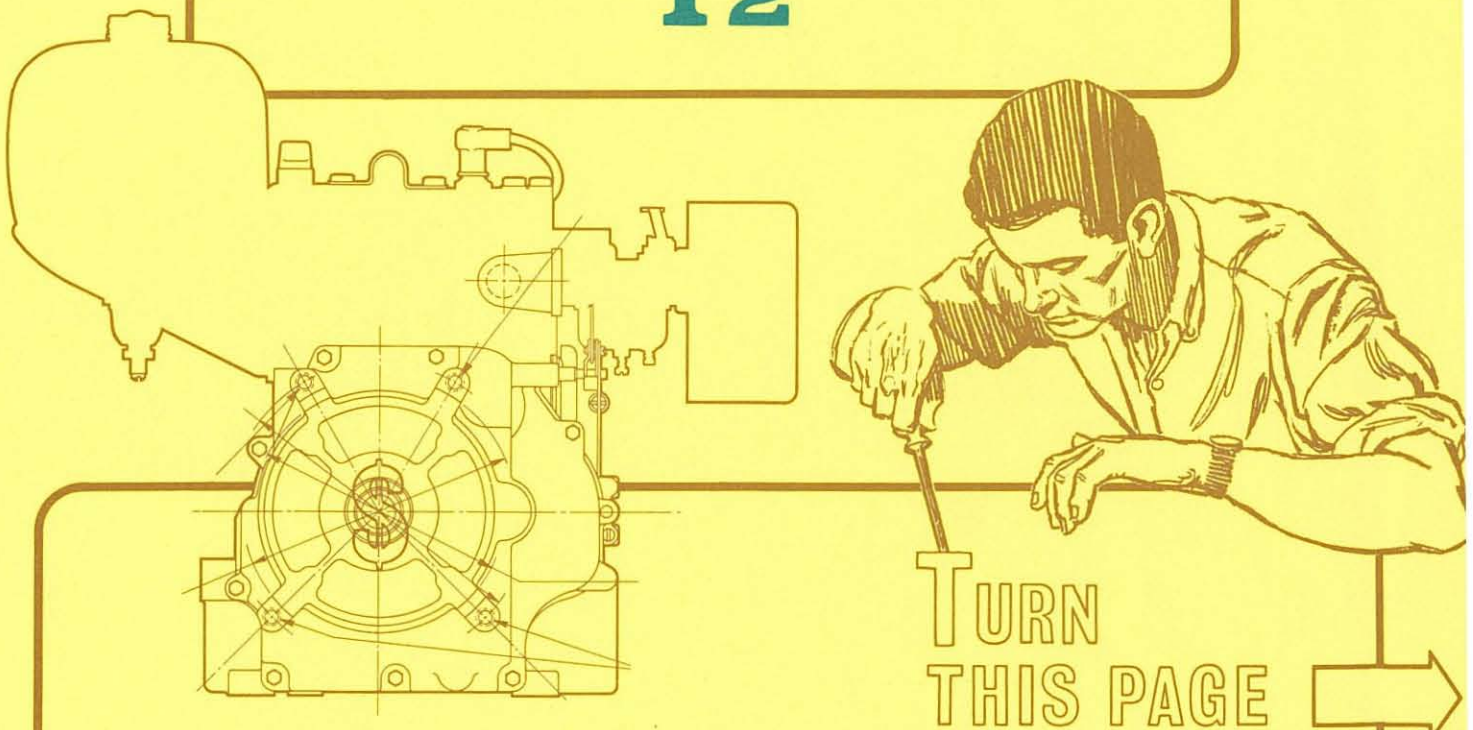
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

12



TURN THIS PAGE

...and let's find out all about -- **FUEL PUMPS**

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FUEL PUMPS

Fuel pumps are generally used on installations where the fuel tank is located beneath the carburetor. They are designed to supply a designated amount of fuel to the carburetor at a constant pressure. They are also used on many engines designed to operate in different positions, such as chain saws. Earlier we studied the design of the diaphragm carburetor. There is also a diaphragm fuel pump. Most pumps used on small engines are of the diaphragm type. The diaphragm is the part of the fuel pump that causes the most trouble. If it leaks the pump will not function properly. The diaphragm is designed to be replaceable. In most cases when the fuel pump is being worked on, the diaphragm should be replaced since they are relatively inexpensive. Once the pump is disassembled for inspection it is just as easy to replace it with a new diaphragm.

Fuel pumps are powered either from a mechanical means or a pressure differential like the diaphragm carburetor. Either method will actuate the diaphragm causing it to pump fuel.

MECHANICAL FUEL PUMP

The mechanical fuel pump obtains its energy from a mechanical arm driven from a cam on either the camshaft or the crankshaft.

Figure 94 shows a typical cam driving mechanism. The cam, shown at A, has an offset or eccentric. This is called the cam lobe. In the position shown it exerts pressure on the pump lever shown at B. This forces the connecting length, shown at C in the upward direction.

When the cam lobe is in the position shown at D it permits the pump lever to go down. As the camshaft continues to rotate the pump lever is forced up and down. This action forces the diaphragm up and down causing the pumping action.

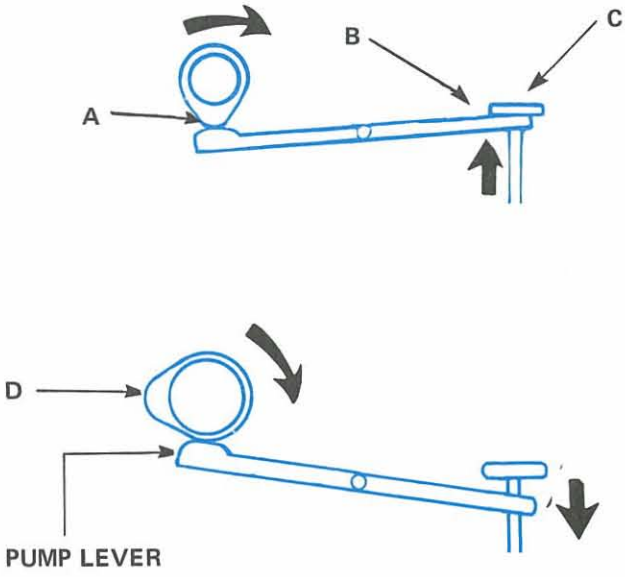


Figure 94

Figure 95 shows how the pump lever actuates the diaphragm of this fuel pump. When the fuel pump lever moves up it creates a suction and draws in fuel from the tank through the inlet valve shown at A.

When the pump lever, shown at B, raises the diaphragm it compresses the diaphragm spring shown at C. This creates a partial vacuum in the pump chamber shown at D. This partial vacuum opens the inlet valve shown at E and allows fuel to enter the pump chamber. This same partial vacuum closes the outlet valve shown at F.

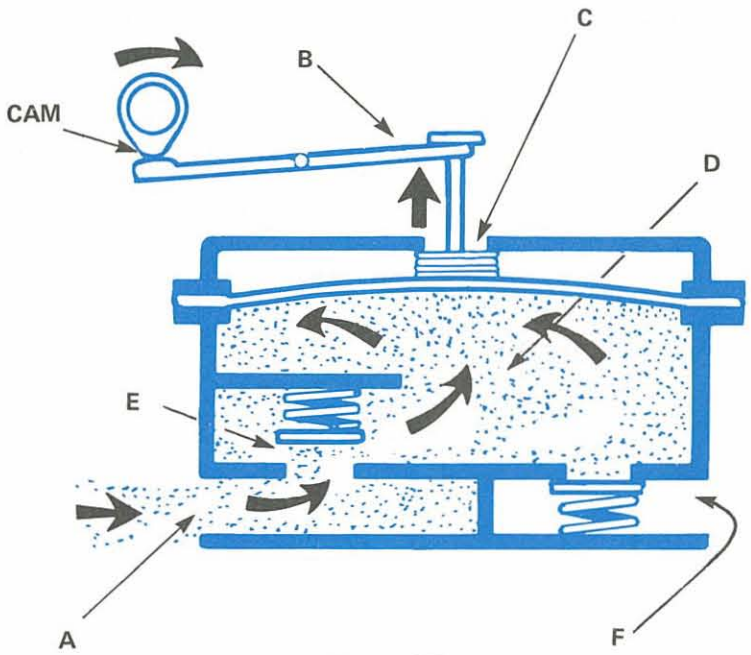


Figure 95

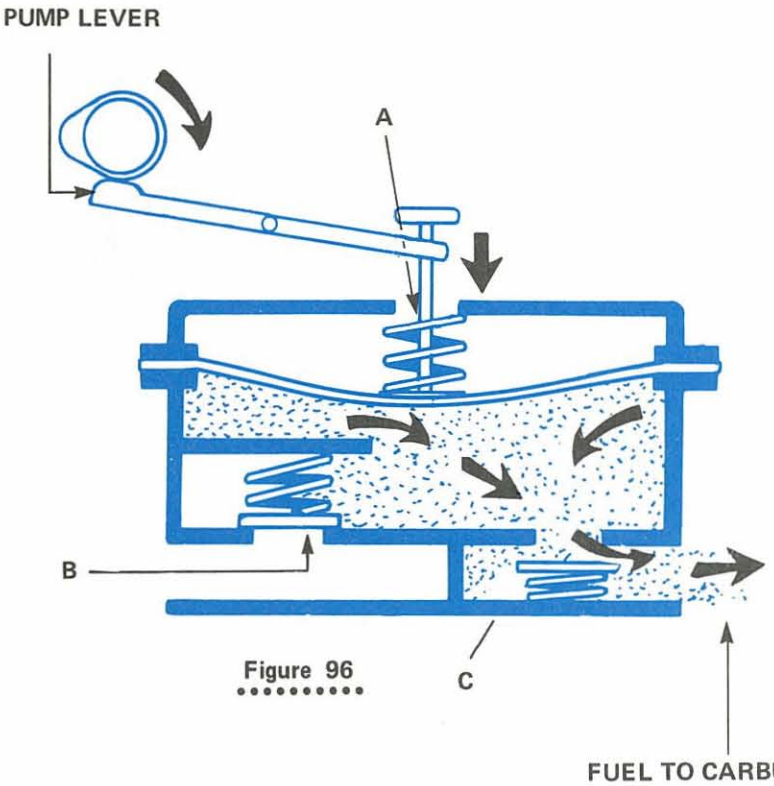


Figure 96

Figure 96 shows how fuel is then forced to the carburetor. As the pump lever releases the diaphragm spring A it forces the diaphragm down. The inlet valve B is closed and the pressure of the diaphragm on the fuel in the chamber forces the outlet valve at C to open.

DIFFERENTIAL PRESSURE FUEL PUMP

The differential pressure fuel pump works on the same basic principle as the mechanical fuel pump except it uses the engine vacuum to create high and low pressure areas on either side of the diaphragm to obtain the pumping action.

Earlier we covered some of the basic principles of the 2-cycle engine that included the pressure differential created when the piston moved up and down in the cylinder. As the piston moves up it creates a low pressure area in the crankcase. As it moves down it creates a high pressure area in the crankcase. These high and low pressure areas are used to operate a pressure differential fuel pump.

Figure 97 shows the basic operation of the pressure differential pump. The low pressure area from the crankcase causes the diaphragm to move up as shown. This causes a suction from the fuel tank which opens the inlet valve shown at A. Fuel then goes directly to the fuel chamber shown at B. The outlet valve shown at C is closed.

LOW PRESSURE FROM CRANKCASE

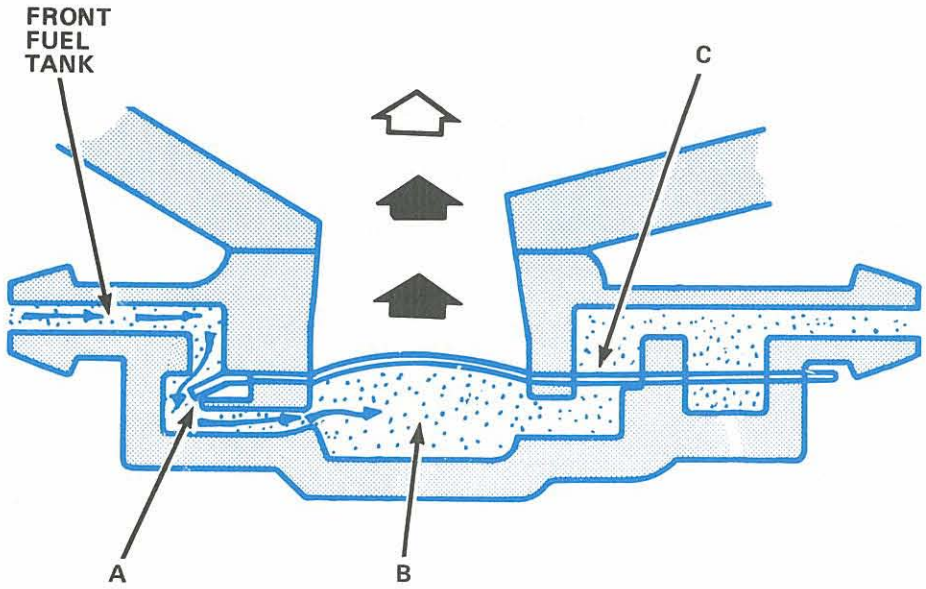


Figure 97

HIGH PRESSURE FROM CRANKCASE

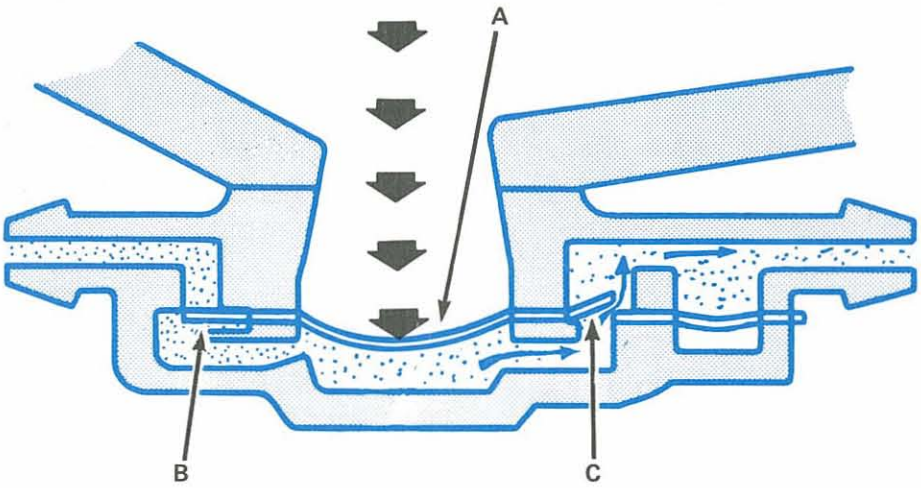


Figure 98

Figure 98 shows the piston going in the other direction. This causes a high pressure area from the crankcase. The pressure shown at A forces the diaphragm down. The valve at B closes. Pressure is exerted on the fuel which forces open the outlet valve at C and forces fuel to the carburetor.

CHECKING FUEL PUMPS FOR OPERATION

Proper functioning of a fuel pump can only be checked under actual operating conditions. Disconnect the spark plug wire and then the fuel line to the carburetor. Turn the engine over with the starter for a few seconds and check the fuel flow. It should have regular surges of fuel coming from the tank. It should not be weak or erratic but should show a steady flow in surges. It will not flow a steady stream.

Figure 99 is an exploded view of a typical fuel pump. If the pump is not operating properly check the condition of the cam lever shown at A. There could be worn or damaged spots on this lever in the area it contacts the cam shaft. Also the connecting length shown at B should be checked for wear. Probably the most common cause of fuel pump trouble is the diaphragm shown at C. This should be checked the same as a diaphragm used in carburetors. You should also check the condition of all springs and the valve body. Sometimes the springs will become damaged or just weak from use and will need to be replaced.

Another part to inspect is the actual valve itself as shown at D. This is just a little different than the valves shown in Figure 96 and Figure 97 but they serve the same principle. This type valve is called a ball valve. The gasket shown at E is very important. If it is worn or damaged it will allow air to be sucked into the pump and effect the operation of the diaphragm.

When disassembling any component such as the pump or carburetor it is always good to lay-the parts out in the order in which they were disassembled. This will help in assembling the unit back together. In most fuel pump repairs it is a good idea to replace all gaskets and the diaphragm.

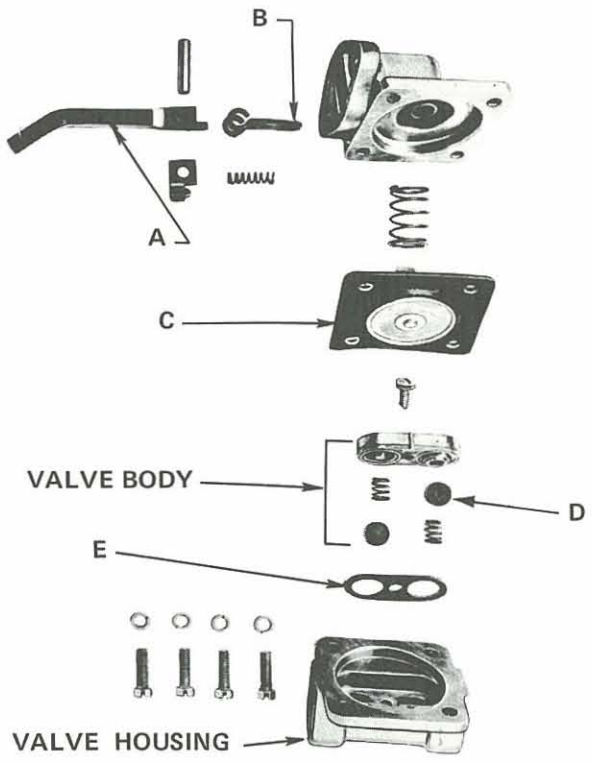
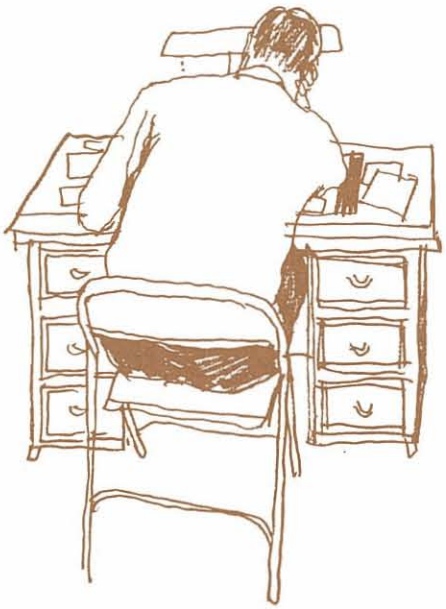


Figure 99



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EXAMINATION ON LESSON 12
FUEL PUMPS

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ANSWER

1. The differential pressure fuel pump uses the same basic principle as the cam operated pump, except it uses the engine vacuum to create high and low pressure.
   TRUE
   FALSE

2. Fuel pumps on most small engines are generally powered from a mechanical means or a pressure differential.
   TRUE
   FALSE

3. When servicing a diaphragm fuel pump, it is recommended to replace all gaskets and the diaphragm.
   TRUE
   FALSE

4. Fuel pumps are generally used on installations where the fuel tank is located _____ carburetor.
   a. on top
   b. beneath
   c. neither of the above

5. All _____ require a mixture of oil with the fuel.
   a. two cycle engines
   b. four cycle engines
   c. both of the above

6. Most pumps used on small engines are of the diaphragm type.
   TRUE
   FALSE

7. List the letters of the parts of the mechanical driven diaphragm fuel pump shown in Fig. 12-1.
   1. fuel from the tank
   2. pump lever
   3. diaphragm spring
   4. pumb chamber with partial vacuum
   5. inlet valve
   6. outlet valve
   7. diaphragm
   8. cam

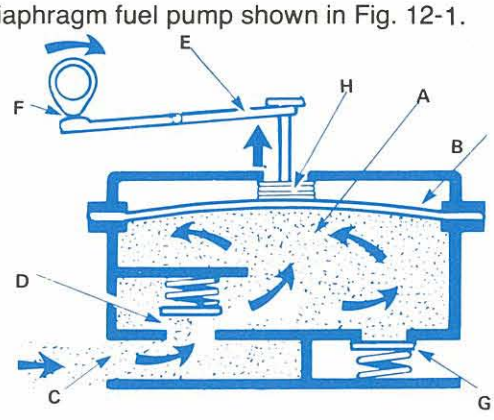

Figure 12-1

C
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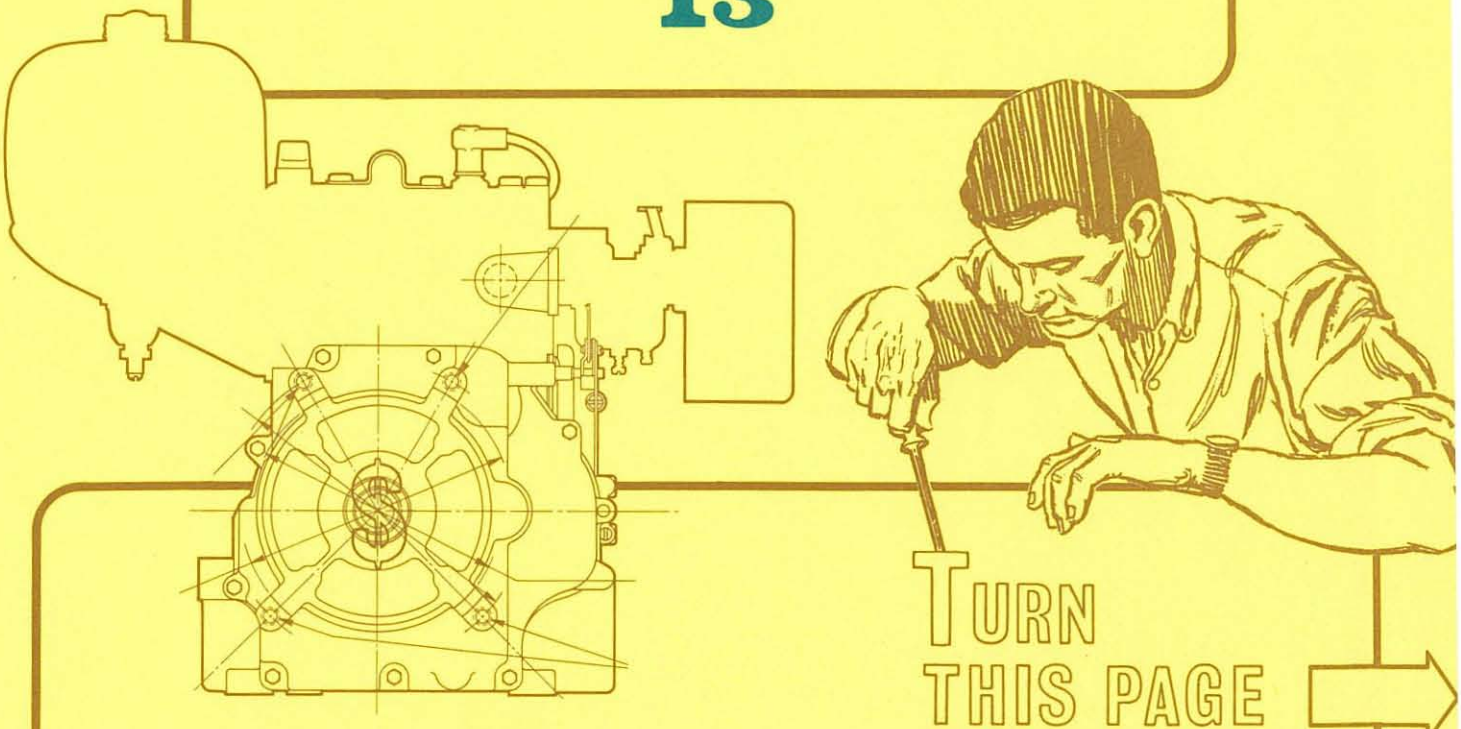
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

13



TURN THIS PAGE

...and let's find out all about -- **GOVERNORS**

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GOVERNOR FUNCTIONS

Almost all small engines are equipped with governors. The function of the governor is to control the engine at the desired speed. Governors are sometimes designed to regulate several different functions of the engine. Some governors are designed to limit the low or top operating speed of an engine. Others are designed to regulate the speed of the engine at whatever setting is selected on the speed control throttle.

Engine manufacturers design and test their engines and select the operating speed best for each model engine and the application it is to be used for.

Most small engines should be operated in the high speed range. At a higher speed the engine has the capacity and time to adjust to a wide range of power demands. The engine speed is controlled by the amount of fuel and air mixture available for combustion in the cylinder.

Engines have many variables that can affect their speed. The governor works with the carburetor so it will deliver the required amount of fuel and air mixture by controlling the throttle valve in the carburetor.

Often the operation of a governor is considered to be a means of controlling or limiting the speed of an engine to keep it from over-speeding. Most governors used on small engines actually have the opposite function. They are used more to prevent the engine from under-speeding. Small engine governors are designed to maintain a constant engine speed under light, medium and heavy loads.

If an engine operating without a governor at a speed of 1,500 RPM encounters a load it will begin to slow down unless some means is provided to increase the fuel and air mixture. Without increasing the fuel and air mixture the engine would begin to slow down as the load is applied and would eventually stop. With the governor functioning properly, the engine speed will remain fairly constant as a load is applied. The more load that is applied, the more the governor will open the throttle, allowing more fuel and air mixture. This goes on to a point of reaching the capacity of the engine.

As the load increases, the governor increases the fuel mixture and, as the load decreases, the governor will cut back on the fuel mixture. This reduces the horsepower output but still maintains the same constant speed.

Cars are generally not equipped with governors because it is necessary that their speed be variable at all times. The engine speed will vary with the same surface speed of the car, depending on the gear the car is being operated in. Some years ago it was not uncommon for some new cars to be equipped with governors to limit their top speed when the engine was new. This is no longer necessary since modern engineering has almost eliminated the need for breaking in new cars.

Engine manufacturers test their engines and decide on the best speed to permit the maximum amount of power to be delivered and still not overexert the engine. This speed varies with different engines and the application they are designed to be used for. The governors are designed to control the engines so they operate in this speed range.

TYPES OF GOVERNORS

Governors must be operated from some force directly related to the engine. It can come from a number of different sources as long as the force is directly related to the engine operating condition.

Governors operate from a vacuum created by the engine, air created by the flywheel, centrifugal force created by the turning of the crankshaft or camshaft or they may be electrical. Almost all small engines use governors operated either by centrifugal force or air. Centrifugal force governors generally obtain their energy either from the crankshaft or camshaft. Air operated governors are operated by air movement caused by the fins on the flywheel.

AIR-VANE GOVERNORS

The basic principle of an air-vane governor can be compared to a fulcrum with one pressure working against the other. If we had a board 6-foot long and supported it in the center on a fulcrum it would balance. Figure 100 shows the fulcrum principle as it would apply to an air-vane governor.

If 30 ounces of pressure caused by air current from the flywheel were applied, as shown at A, the force as shown at B would be set to create 30 ounces of pressure to be exerted in the direction shown by arrows. This spring pressure would equalize the pressure exerted by the air from the flywheel.

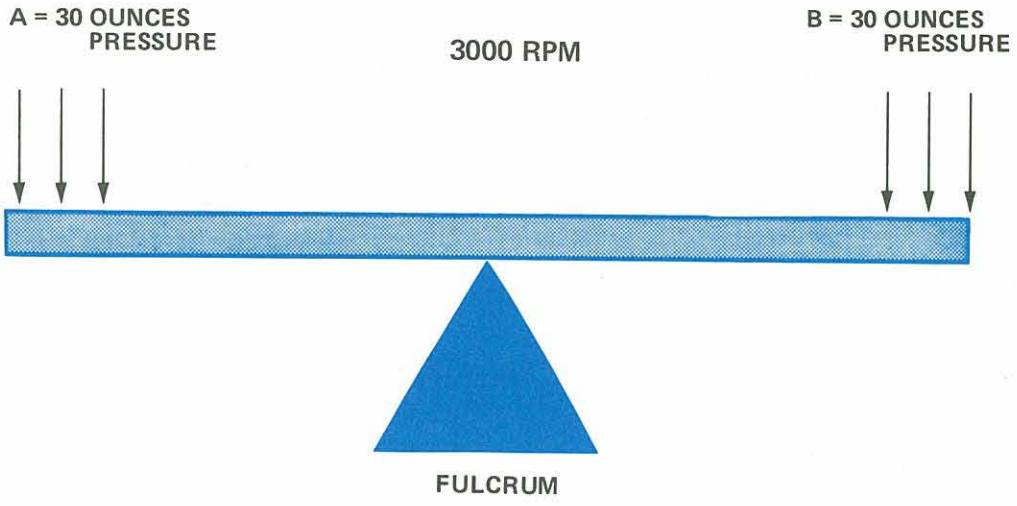


Figure 100

If an engine operating at 3,000 RPM exerted 30 ounces of pressure that was equalized by the spring giving the same pressure the fulcrum would remain level as shown. Suppose the engine begins to slow down to 2,000 RPM as shown in Figure 101. The air pressure from the flywheel would reduce to 2,000 RPM as shown at A. The spring pressure shown at B would also be reduced to 20 ounces of pressure. The fulcrum is still in balance as long as the pressure A equals pressure B. This is the basic principle of the air vane governor. The spring is adjusted to offset the air pressure exerted against the air vane.

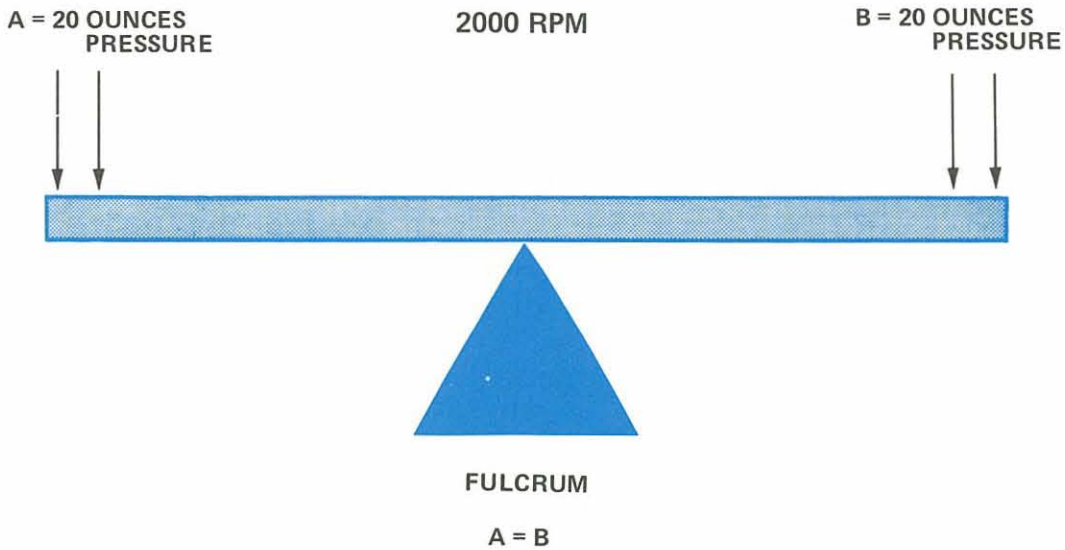


Figure 101

The air vane governor is sometimes known as a pneumatic governor. Figure 102 shows a typical air vane governor. Earlier we covered the flywheel housing and how it diverted the air turbulence caused by the flywheel to the engine for cooling. This same air turbulence caused from the turning flywheel supplies the energy to operate the air vane governor which, in turn, controls the fuel and air mixture to the carburetor.

The fins on the flywheel shown at A, create an air current when the flywheel is turning. Figure 102 shows the engine stopped and no air is being directed to the vane shown at B. The throttle valve shown at C is in the open position. It is held in the open position by the spring tension shown at D. This spring tension can be adjusted for more or less tension by the adjustment nut shown at E. The tension of the spring and the amount of pressure exerted on the air vane by the movement of the flywheel can be equalized to control the engine to a predetermined operating speed.

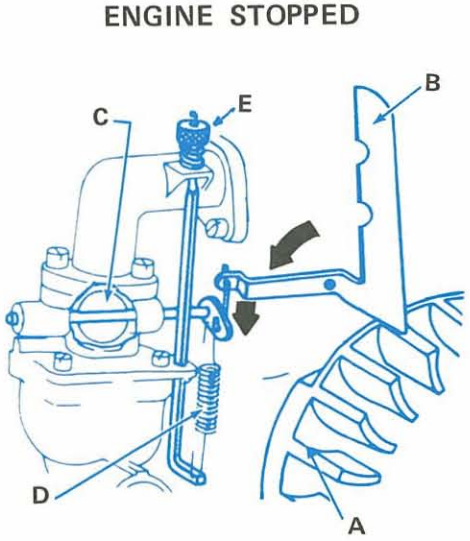


Figure 102

Figure 103 shows what happens when the engine is running. The flywheel shown at A creates an air pressure or current that is exerted directly against the air vane shown at B. The air vane is connected to a control arm shown at C. As the air vane moves in the direction of the arrows caused by the flywheel turning, it raises the control arm which begins to close the throttle shown at D. The amount the throttle valve closes is determined by the amount of spring pressure and the speed of the flywheel. If the adjusting nut shown at E is loosened it will allow the control rod F to be lowered and exert more tension on the spring. This added tension will lower the control arm and allow the throttle to be opened more. The engine will then speed up. As it speeds up, more air is driven against the air vane, from the flywheel that is now turning faster. As the air vane gradually moves from this force, it will start to close the throttle. Notice that the governor action is working against the spring action.

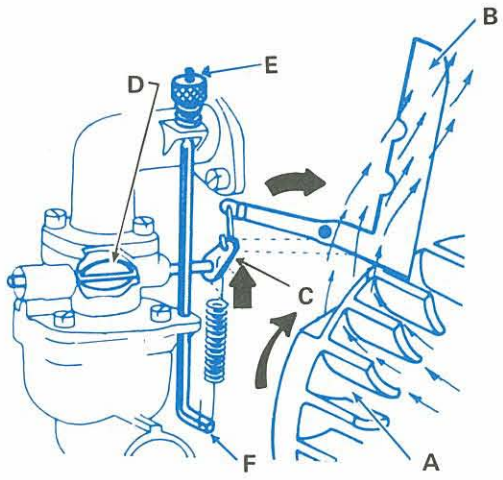


Figure 103

CENTRIFUGAL FORCE

A weighted object, rotated around a center point, creates a centrifugal force that is in relationship to the weight of the object and the speed at which it rotates around the center point. As the speed increases centrifugal force causes the weighted object to move away from the center of rotation. The weight moves away in direct relationship to the speed and its weight until it reaches an equalization point where the weight is at right angles to the point of rotation.

Figure 104 shows the basic principle of centrifugal force. There is a weighted object rotating around point A. The weighted object shown at B is at rest and the point of rotation A is not turning. As point A begins to turn, the weight will begin to move out away from the center as shown at C. As the speed increases the weight will move further out away from the center, as shown at D and E. Finally, the speed and the weight are equalized. The weight will be at right angles to the point of rotation as shown at F.

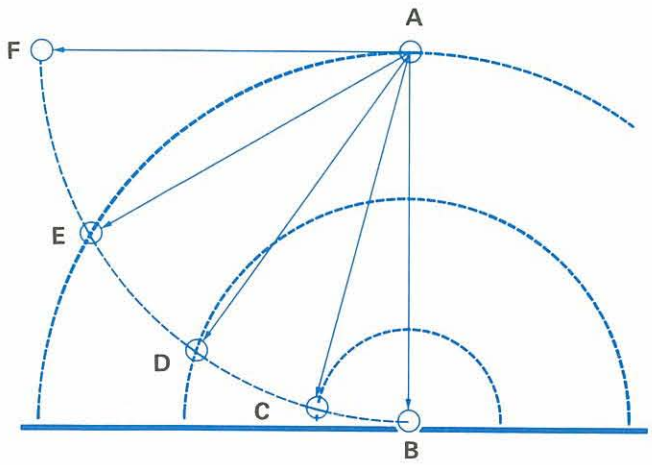


Figure 104

Suppose the rotating point was traveling at 1,000 RPM and the weight was in the position shown at F. The speed and the weight would be equalized. If the weight were increased and the speed remained the same, the weight would drop down to one of the lower positions. The amount of weight increase would determine the amount it would drop.

This increase in weight is not accomplished by actually increasing the weight but by the addition of an adjustable spring or linkage that acts the same as increasing the weight.

CENTRIFUGAL GOVERNOR

The centrifugal governor, as the name implies, uses the principle of centrifugal force to control an engine to the desired speed. Figure 105 shows the operating principle of a typical centrifugal force governor with the engine stopped. Most governors have four principal parts; the governor gear, fly weights, spool and the governor shaft. The gear shown at A is turned either by the crankshaft or the camshaft. This gear turns the governor gear shown at B. When this gear is stopped or turning at a very low speed, the fly weights, shown at C, are in the retracted position. When you adjust the throttle control, shown at D, to increase the speed additional tension is exerted on the control spring shown at E. This spring tension opens the throttle valve and the engine speeds up. As the engine speed increases, the centrifugal force causes the flyweights to move away from the center rotation.

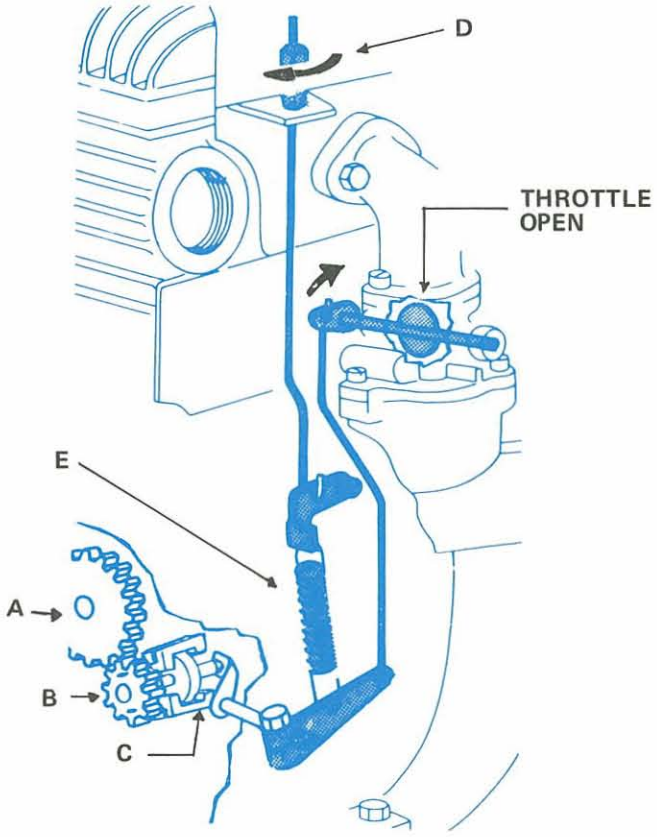


Figure 105

Figure 106 shows the engine in operation. The flyweights, shown at A, are extended out away from the center of rotation. As these weights extend out they force the spool, shown at B, to the right. The spool actuates the lever linkage and causes the arm C to move down and begin closing the throttle. Notice the governor action is working against the spring action.

The rotation of the arm C overcomes some of the spring tension and begins closing the throttle valve until the throttle linkage tension from the control spring equals the force created on the spool by the flyweights.

If more load is added to the engine, it will tend to slow down. This reduces the centrifugal force on the flyweights and they will begin moving back toward the center of rotation as shown in Figure 105. When this happens, the throttle begins to open allowing more fuel to enter the combustion chamber and the engine speeds up.

This governor action of opening and closing the throttle may seem that the engine is constantly going up and down in power. Actually these actions take place so fast that the fuel consumption area of the engine is not affected by these pulsating off-and-on motions of the governor. These motions are not actually off-and-on but gradual movements that create a smooth running engine.

An improperly operating governor will cause the engine to go up and down in RPM and cause an uneven supply of fuel to be delivered to the engine. This condition is called surging.

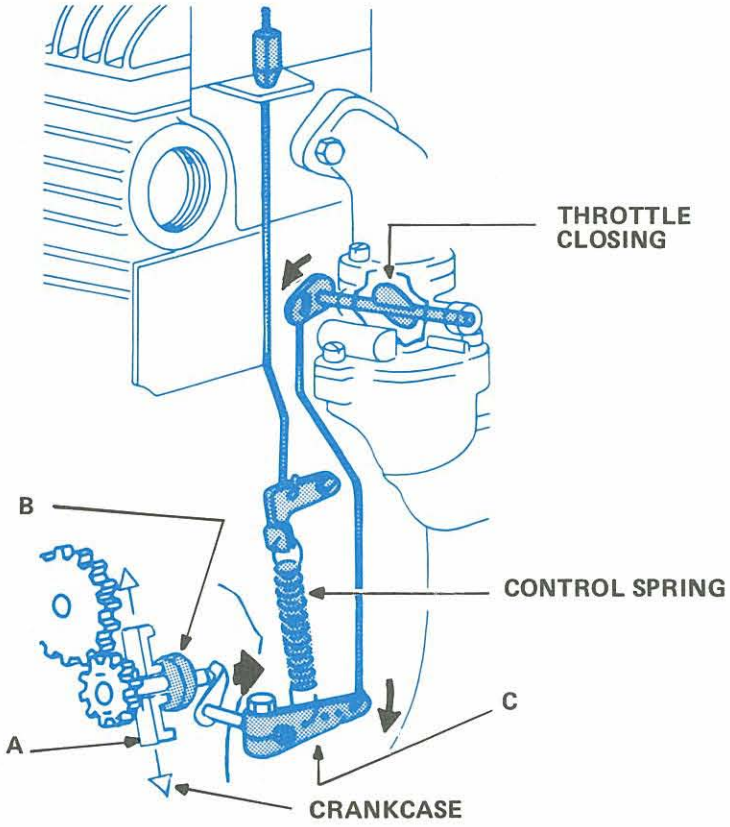


Figure 106

GOVERNOR ADJUSTMENTS

When a governor is in proper operating condition and the adjustments are correct the engine will respond quickly to any change in load. It should maintain the correct engine speed without surging. There is a very critical balance between the control spring and the air vane or flyweights. The governor is often blamed for improper function of an engine simply because it is the direct controlling factor for allowing fuel to the engine. Before deciding that engine trouble is caused by the governor several other points should be checked such as fuel, ignition and compression.

Clogged cooling fins will restrict the flow of air necessary to operate an air vane governor. This trouble is particularly common on engines used with lawnmowers. Grass being cut is being sucked into the area of air turbulence caused by the flywheel. It becomes imbedded between the flywheel and the cover shroud. Almost any lawnmower brought in for repair will have an excess accumulation of grass and other foreign matter packed in this area. Before making any adjustment on a governor it should be checked over carefully to be sure all parts are free without any restriction of movement. Check for worn connections or ones that are bent or binding. All linkages should operate free. The air vane should be checked to be sure it is not bent, damaged or restricted. It must operate free, with the return spring bringing it back to position.

When the engine is stopped the throttle valve should be in the open position. Improper adjustment of the linkage may cause it to be only part way open.

The speed-sensing element on air vane governors is easily checked for freedom of movement, however, it is difficult to check the speed-sensing element on centrifugal governors because of their location. It is generally necessary to remove part of the engine to actually get to the governor unit. Fortunately the centrifugal governor very seldom causes trouble and it can be checked for mechanical wear or damage of the parts when the engine is disassembled.

There are many different ways provided for governor adjustments. Each design, make and model of engine could have some variation in their adjustment procedure but, basically, they are very similar. Regardless of the method used to make the adjustment, the primary object is to balance the tension spring against the governor action. These variations in adjustments are principally due to linkage design.

Figure 107 shows one method of changing the effective length of the throttle control arm by changing the linkage to different holes. The governor adjustment screw is shown at A. Either the spring tension or the length of the control linkage can be changed by moving them to one of the other holes in the arm shown at B.

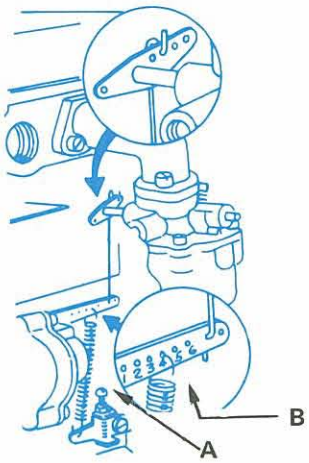


Figure 107

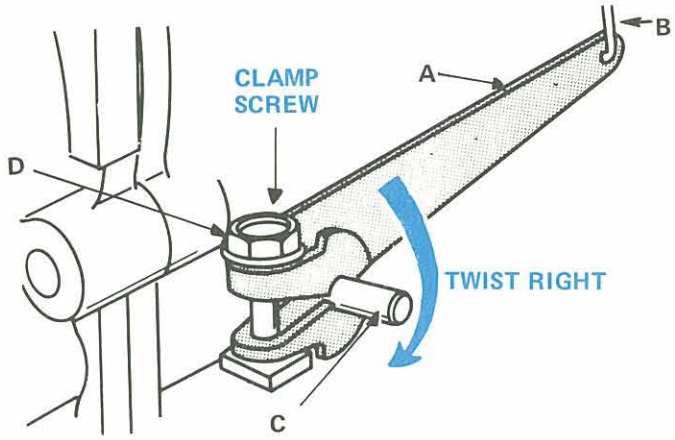


Figure 108

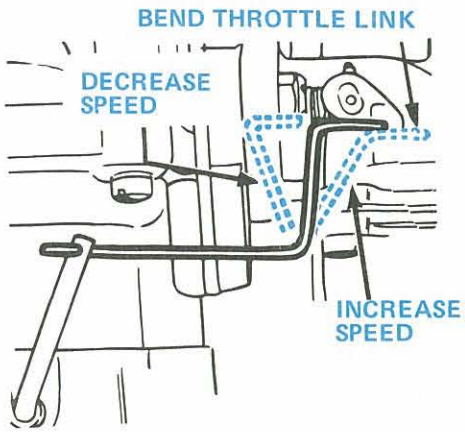


Figure 109

Another method is shown in Figure 108. The governor lever shown at A controls the linkage going to the carburetor. The linkage going directly to the carburetor is shown at B. The governor lever is connected to the governor shaft at C. This clamp is adjustable.

The clamp screw shown at D can be loosened so the lever can be set to the desired position and then locked in place. This adjustment permits equalizing the force of the spring against the governor flyweights.

Another method of adjustment is shown in Figure 109. By bending the throttle linkage as shown the length can be either increased or decreased.

Some linkages are provided with an adjustment screw design as shown in Figure 110. The locknut shown at A can be released and the speed adjustment can be made with the adjusting screw shown at B.

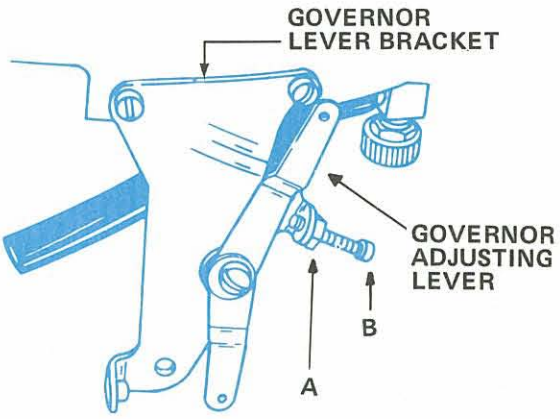


Figure 110

Other flyweight governors have an adjustable flyweight collar as shown in Figure 111. This collar has a lockscrew that holds it in position on the shaft. By loosening this screw, the collar can be moved up or down which will change the position of the flyweights shown at A.

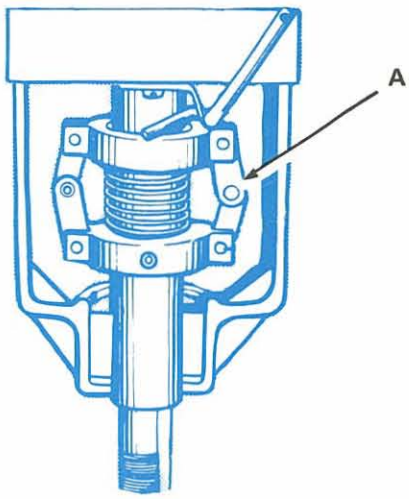


Figure 111

ENGINE SPEEDS

There are three basic engine speeds used on small engines. The idle speed on most engines is around 1,800 RPM for both 2-cycle and 4-cycle engines. There are two other speeds to be considered on most governed small engines. They are, no load operating speed and full load operating speed. Most small 2-cycle and 4-cycle engines operate efficiently in the speed ranges shown below:

	RPM IDLE	RPM OPERATING SPEED	RPM FULL LOAD SPEED
2-cycle	1800	3500	3200 to 3300
4-cycle	1800	2800	2500 to 2600

The full load operating speed is generally 200 to 300 RPM lower than the no load operating speed. This will vary a little with different engines but these figures can be used as average. To obtain the exact engine RPM it is necessary to use a tachometer. A vibration tachometer is the most practical to use for checking engine RPM.

Most small engine repair shops depend on the sound of the engine for adjusting and setting the carburetor and governor. After a little experience with small engines you will be able to hear the engine when it is at its best idle and operating speed. Chain saws generally operate at about 9000 RPM.

ENGINE SPEED AND APPLICATIONS

An engine is designed or selected for the applications it is to be used with. The proper horsepower must be selected to operate the machine at its rated capacity. Because of price, weight and size of the engine selected to operate a machine is generally just adequate in horsepower with very little or none to spare. This requires operating the engine at near its maximum or full speed.

Rotary lawnmowers are especially critical to engine speed since most of them are directly driven from the crankshaft. These rotary blades should have a rim speed, or blade tip speed, of not more than 19,000 to 20,000 feet per minute. The length of the blade and the RPM it is turning will determine the blade tip speed. Blade tip speed can easily be figured by a mathematical formula and example as shown in Figure 111A. The blade feet per minute speed increases by more than 5,000 feet per minute by increasing the length of the blade from 18 inches to 24 inches.

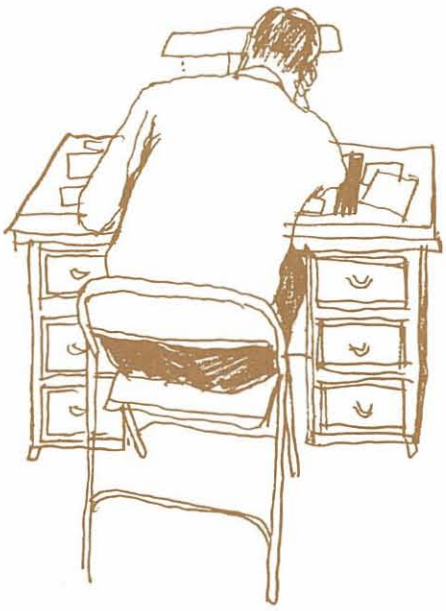
Blade length in inches times 3.1416 times RPM, divided by 12 inches equals feet per minute blade speed.

$$\frac{BL \times 3.1416 \times RPM}{12} == \text{feet per minute}$$

Example:

18"
x 3.1416
56.5488
x 3300
186611 ÷ 12==15,550

Figure 111A



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

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STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

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INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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EXAMINATION ON LESSON 13
GOVERNORS

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NAME _____ Student No. _____
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ADDRESS _____ Date _____

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Air operated governors are operated by air movement caused by the turning flywheel. — T
   TRUE
   FALSE

2. As an engine load increases, the governor will cut back on the fuel mixture. — _____
   TRUE
   FALSE

3. Centrifugal force governors generally operate off of the air turbulence created from the turning flywheel. — _____
   TRUE
   FALSE

4. Governors on small engines may be operated by _____. — _____
   a. vacuum
   b. air turbulence created from moving flywheel
   c. centrifugal force
   d. all of the above

5. The function of a governor on small engines is to control the engine to the desired speed. — _____
   TRUE
   FALSE

6. A air vane governor is sometimes known as a pneumatic type governor. — _____
   TRUE
   FALSE

7. Governors are designed to control the low and top operating speeds. — _____
   TRUE
   FALSE

8. Both two cycle and four cycle engines have an idle speed of around _____ RPM. — _____
   a. 1800
   b. 3000
   c. 4000

9. As an engine load increases, the governor will open up the throttle more. — _____
   TRUE
   FALSE

(Continued on page 2)

10. The most commonly used governors on small engines are operated either by air turbulence from the moving flywheel or centrifugal force.
    TRUE
    FALSE

11. The governor gear, the flyweights, the spool, and the governor shaft are the four principal parts of the centrifugal governor.
    TRUE
    FALSE

COURSE Of

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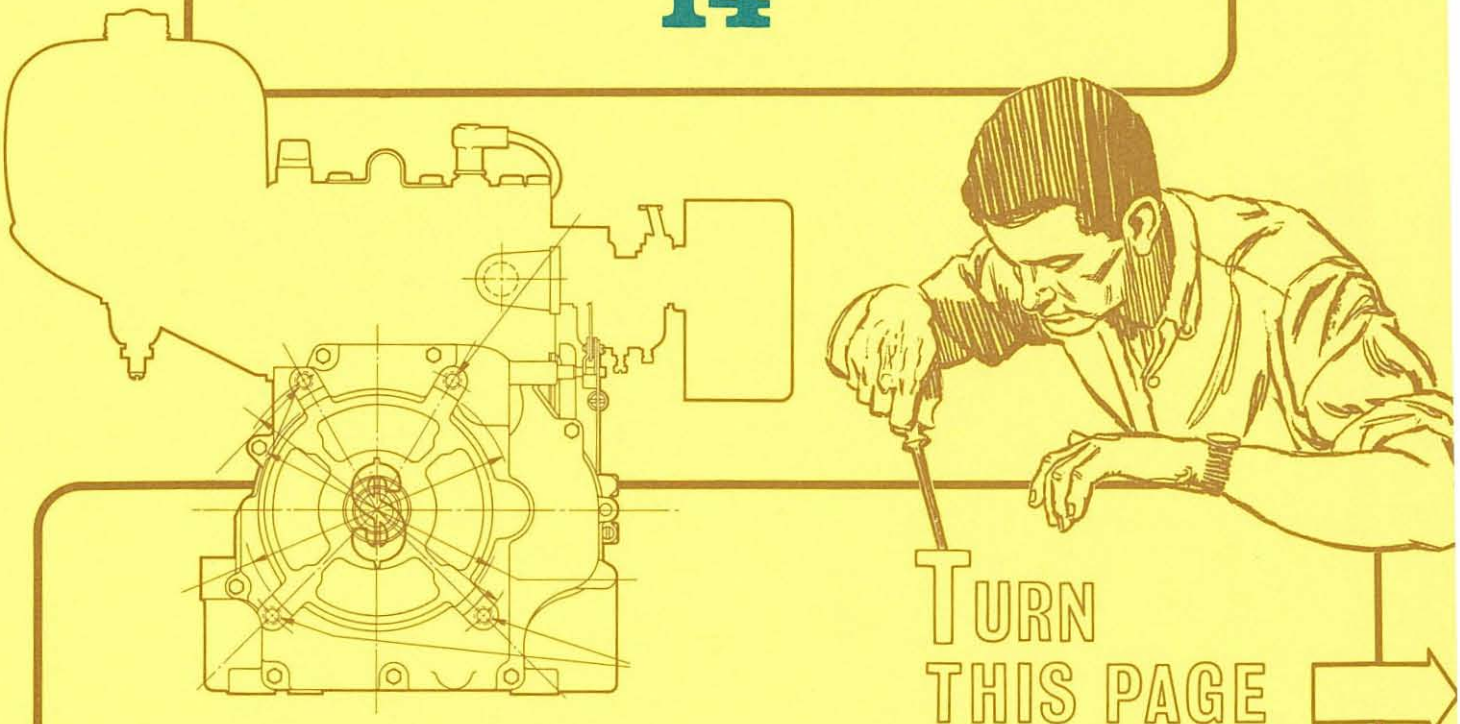
LESSON NUMBER

14



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...and let's find out all about -- MANUAL STARTERS

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STARTERS

Most small engines take a great deal of punishment. Operators will not take proper care of a small engine like they would with their automobile. Often they are used only on an occasional basis and many operators just simply do not take the time to even give them minimum maintenance and care. This is one of the reasons they have always been known as troublesome little engines. Lack of proper care, more than use, is one of the reasons for the shortage of qualified small engine repairmen. As a result of this lack of maintenance, the starter is often overworked. There are a number of different types of starters, however, they basically are either rope-rewind, wind-up or electric.

STARTER FUNCTIONS

The purpose of the starter on an engine is to provide a means for turning the crankshaft until the engine begins its combustion cycle. After this cycle is started the engine will continue to repeat the cycle as the engine runs. In order to start an engine the crankshaft must be turned fast enough for a combustible fuel and air mixture to be drawn into the combustion chamber. It is then compressed and ignited by the spark plug causing an explosion which begins the engine cycle.

Once this takes place the starter releases and the engine continues to run. There must be some mechanical means of supplying this necessary force to begin turning the crankshaft. The starter provides this force either by manual or mechanical means. Manual starters are used on most engines less than 5 horsepower. Over 5 horsepower, an electric starter is generally used. In recent years, there has been a number of small engines used on lawnmowers equipped with electric starters and there is much evidence that they will become more popular and be in more general use.

Every starter must have a driving mechanism to engage the crankshaft. It needs a means of transmitting power to the crankshaft and of disengaging this mechanism from the crankshaft immediately after the engine starts. The basic principle of one of the simplest starters is shown at Figure 112. This simple starter was used on many engine designs several years ago. Many refinements of this basic design have taken place in the past few years. The pulley shown at A is attached to the crankshaft at point B. When the pulley is turned the crankshaft will turn. The rope at C fits into the slot shown at D. There is a knot in the end of the starter rope to keep it from coming out as the rope is being pulled. The angle of the slot in the pulley is designed so that it will release the rope at the end of the pull.

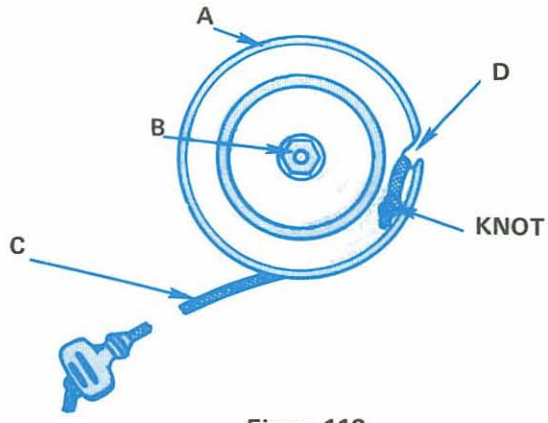


Figure 112

ROPE REPLACEMENT

Most starting ropes are made of a nylon-braid material. The rope should be cut to a length of 4 to 5 feet so it can wind around the pulley four to five times and still have about 6 inches left for space between the pulley and the T-handle and an extra 6 inches for the rope knots.

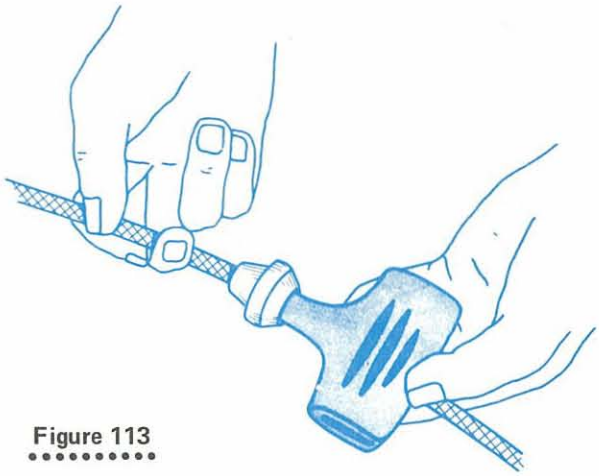


Figure 113

After the rope has been cut to length, insert it through the handle as shown in Figure 113. The frayed ends of the rope will make it difficult to insert it through the hole in the handle. You can hold a lighted match or candle under the end of the rope and it will melt the nylon-braid into a solid mass. This will keep the frayed ends together and make it much easier to slip through the handle.

The proper knot is important to make a starter rope that will not become untied. You can use a "figure-eight" knot as shown at Figure 114. Follow steps 1 through 3 to make the "figure-eight" knot.

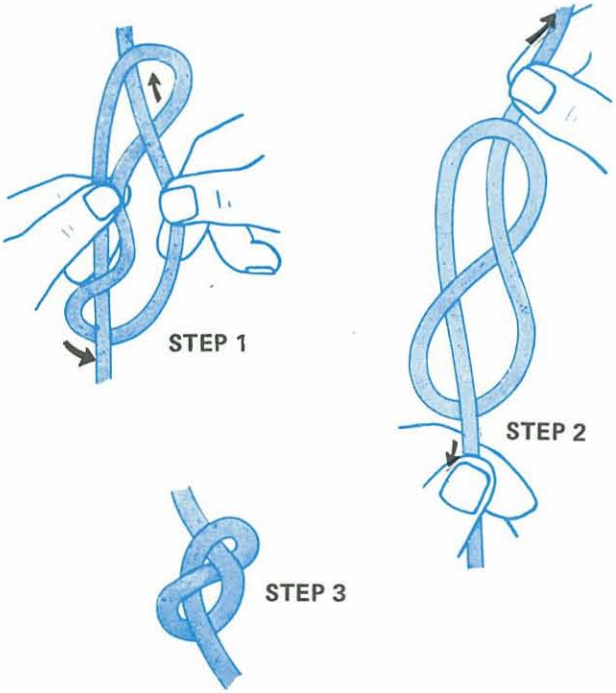


Figure 114

Figure 115 shows the "double-overhand" knot that is also acceptable for starter ropes To make this knot, follow steps 1 through 4.

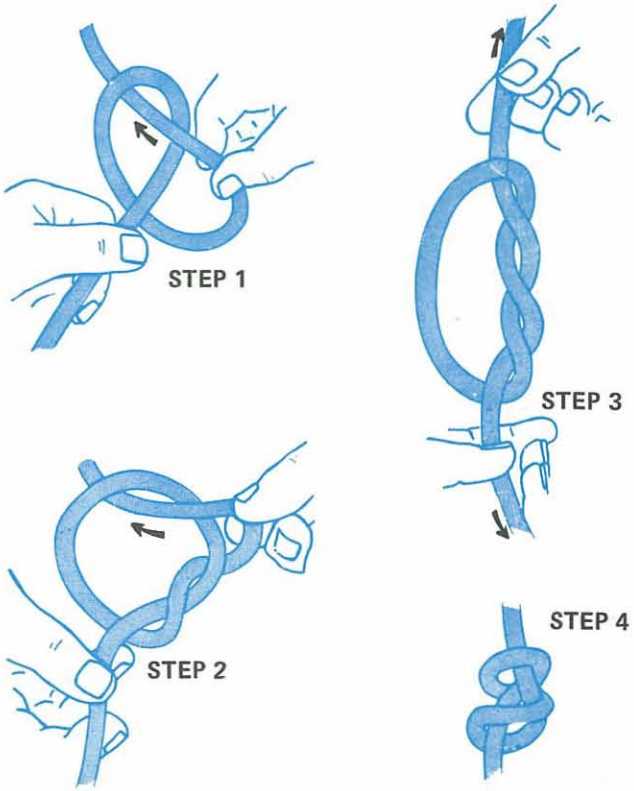


Figure 115

ROPE-REWIND STARTERS

The rewind starter operates similar to the rope-wind starter shown at Figure 112, except it is a little more automatic. This is one of the most popular starters used on small engines. After each pull the rope is automatically rewound by a recoil spring. The rope is permanently attached and there is a mechanical means of engaging and releasing the starter drive from the flywheel. Figure 116 shows a typical rope rewind starter.

ROPE-REWIND STARTER

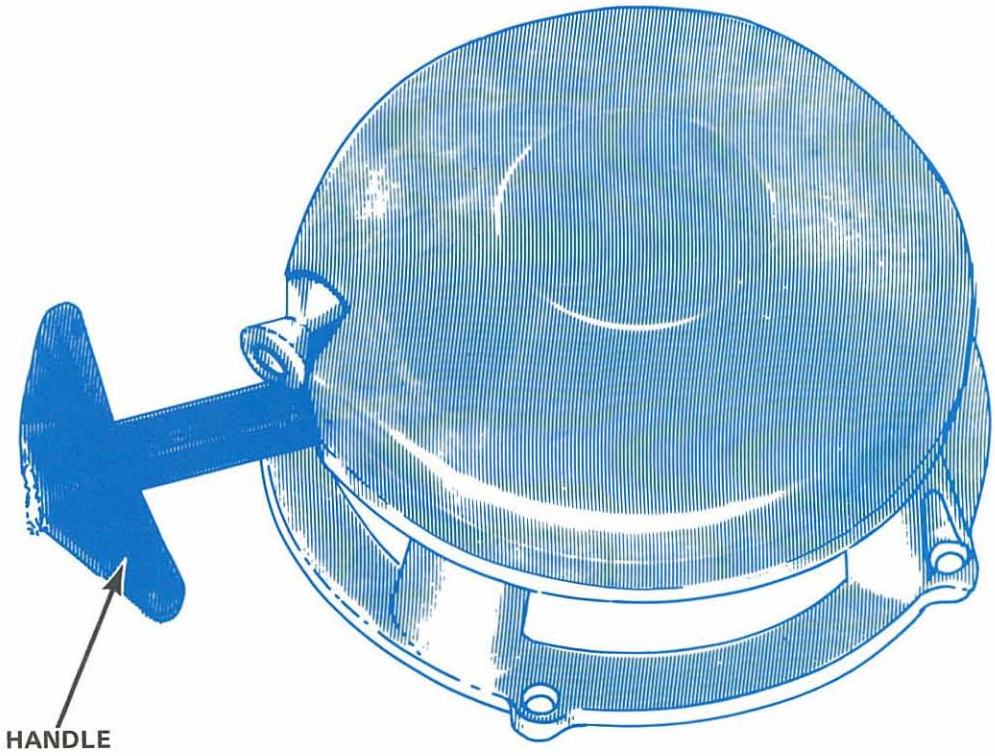


Figure 116

The entire starting unit is bolted to the engine and can be removed for repair or replacement. All of the return and spring mechanism are contained in this housing.

The simple rope-wound starter shown at Figure 112 has practically no maintenance or repair problems except the rope. The rope should be long enough to give three to five complete turns around the pulley. One complete pull of the rope will give three to five turns of the crankshaft which is adequate for starting small engines if they are in proper operating condition.

Any type of automatic rewind starter can be dangerous and must be handled carefully. The outward appearance of these starters would give no indication of the vast amount of potential energy stored within them. When the spring that operates these starters is wound under pressure it can literally explode if not unwound properly when disassembling.

This spring is some 6 to 8 feet long and when released suddenly can fly all over the shop with tremendous force. The rope-rewind starter saves the trouble of rewinding the rope on the flywheel pulley each time the engine is cranked and saves considerable time in starting an engine.

Figure 117 shows an exploded view drawing and parts list of a typical rope-rewind starter. By studying this drawing carefully you should be able to see the relationship of the parts. It would be a good idea to familiarize yourself with the names of these parts and their appearance.

These are the basic parts used in most rope-rewind starters and you should have a working knowledge of how these parts are associated with each other, what they look like and their names.

The starter cup screen shown at 11 and the starter cup at 12, washer at 13 and the flywheel nut at 14 are all connected directly to the crankshaft and are turning when the engine is running. All the other parts are disengaged or in use only when the engine is being cranked for starting.

REF. NO.	PART NAME
1	Screw, Retainer
2	Retainer,
3	Spring, Brake
4	Dog, Starter
5	Spring, dog
6	Pulley
7	Spring & Keeper Assy.
8	Housing Assy., Starter
9	Rope, Starter
10	Handle Assy., Starter
11	Screen, Starter cup
12	Cup, Starter
13	Washer, Belleville
14	Nut, Flywheel

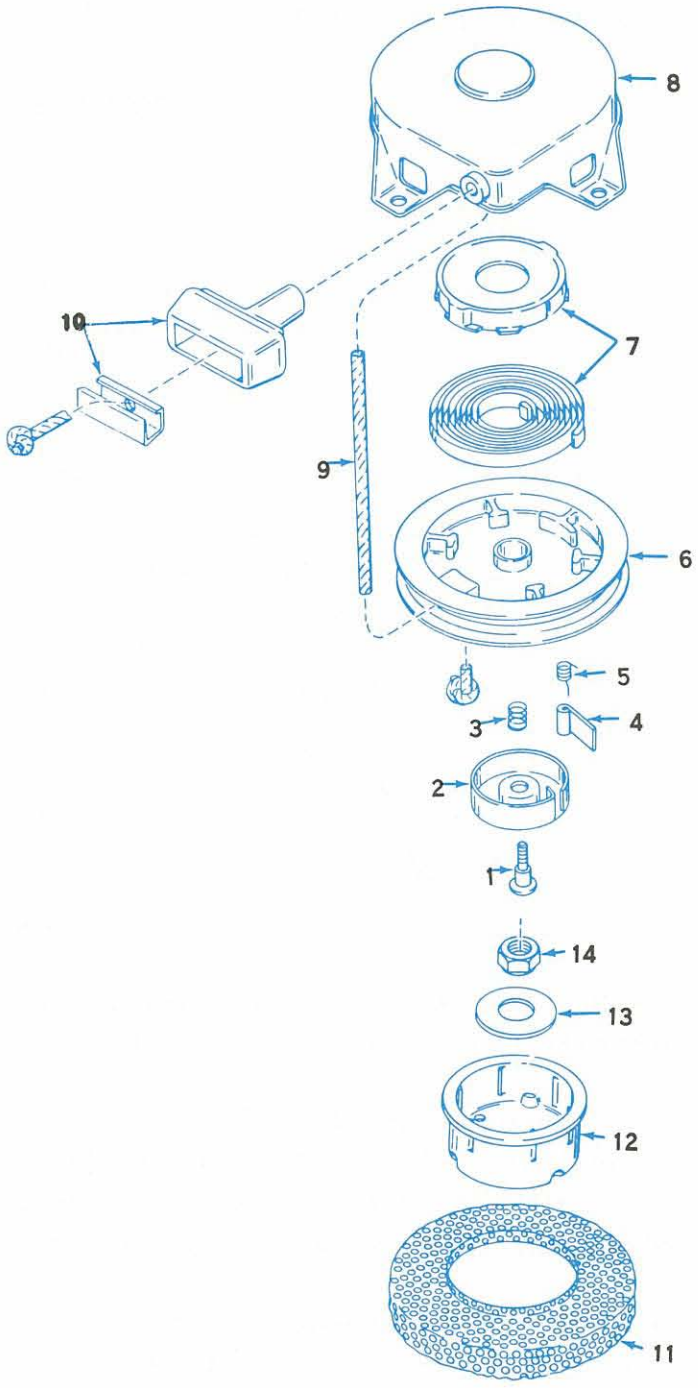


Figure 117

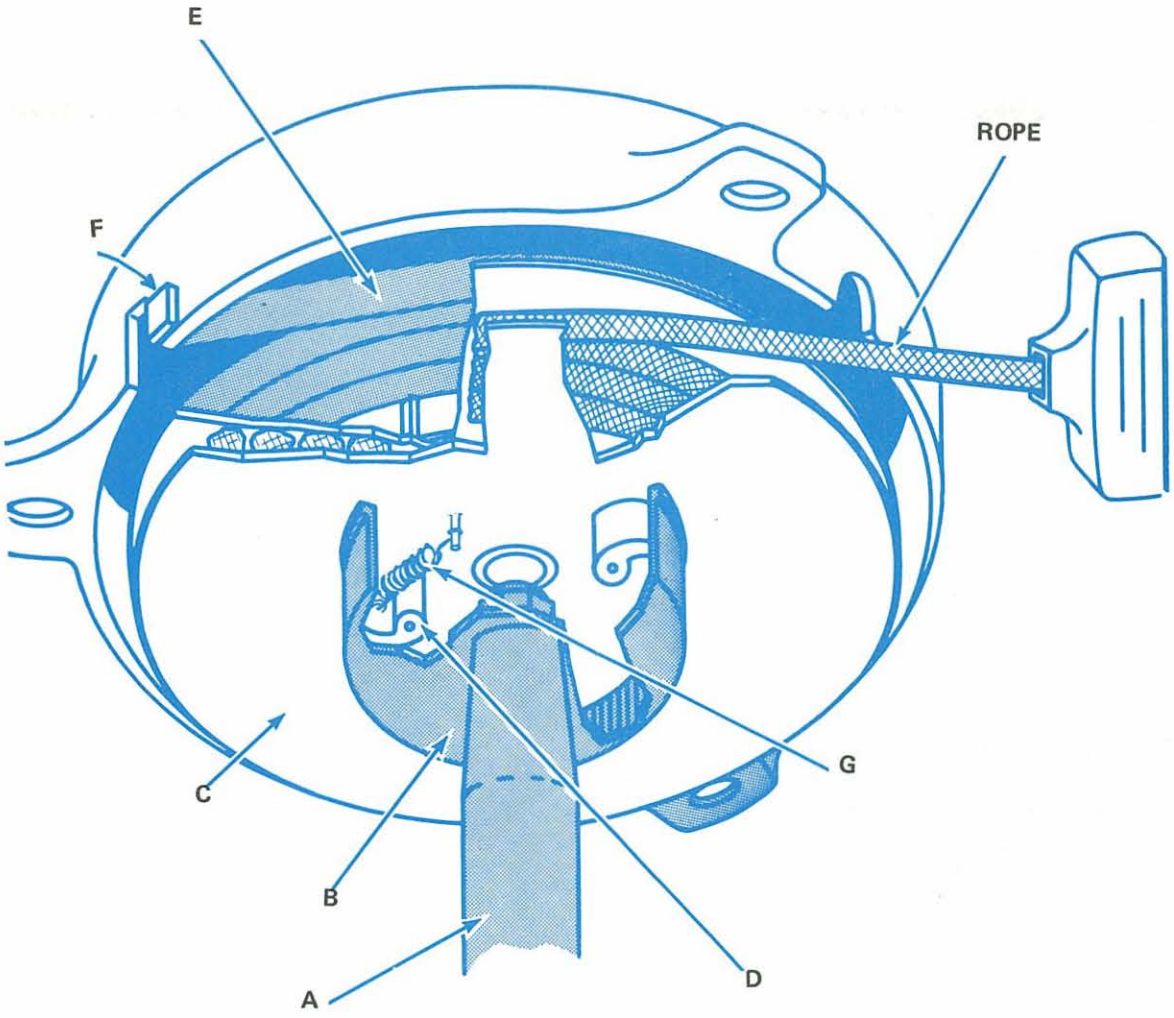


Figure 118

Figure 118 shows the basic operating principle of the rope-rewind starter. The mechanical method used to engage and disengage the pawl may not be the same in different designs, however, the basic operating principle will be very similar.

The chankshaft, shown at A is at the top part of the engine. The chankshaft adapter shown at B is attached directly to the crankshaft and turns when the crankshaft is turning. This part is generally protected with a piece of course mesh steel to keep out foreign matter and to prevent this spinning part from becoming tangled with anything.

The crankshaft and the crankshaft adapter and the starter cup screen are the only parts directly connected to the engine when it is in operation.

The pulley is shown at C. When you pull the rope, the starter pulley is turned. The pawls, shown at D, fly out either by centrifugal force or by a spring loaded action that forces them out when the pulley is turned. The drawing shows two pawls. Many starters have only one pawl. The pawl is often called a starter dog or other similar names.

When the starter rope is pulled, the pawls engage the crankshaft adapter, sometimes known as the starter cup, and turn the crankshaft. As the starter pulley is being turned the recoil spring, shown at E, which was in the rest position, is brought under tension. The further the rope is pulled the more tension is exerted on the recoil spring. One end of the spring is attached to the pulley and the other end is attached to the housing shown at F.

When you release the rope, the pulley is turned in the opposite direction by the force of the spring. The pawl springs, shown at G, retract the pawls away from the crankshaft adapter so there is no connection between the starter and the turning crankshaft. Both the crankshaft and the crankshaft adapter will be turning if the engine starts. The pulley will be turned in the opposite direction and the pawls disengaged from the crankshaft adapter whether or not the engine starts.

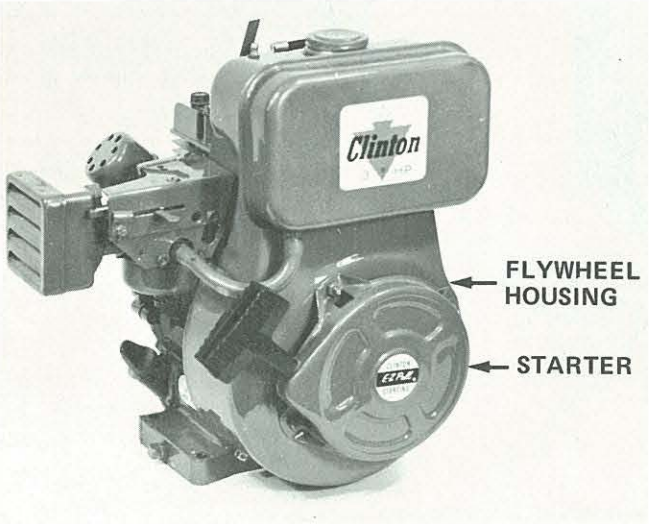


Figure 119

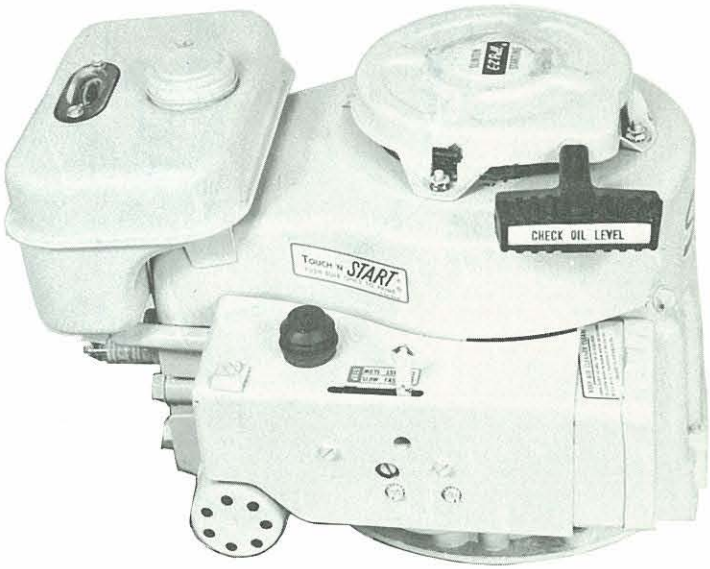


Figure 120

REWIND ROPE REPLACEMENT

Rewind rope starters will generally be either side-mounted or top-mounted. Side-mounted starters similar to the one shown in Figure 119 are used on engines with horizontal shafts. Figure 120 shows a typical top-mounted starter used on some vertical shaft engines. Many vertical shaft engines also use a side-mounted starter with a gear that engages the flywheel for turning the crankshaft.

In order to replace the rope, it is first necessary to remove the complete starting unit from the engine. Some units are enclosed in the flywheel housing or directly to the engine. There are many variations of securing the housing. It may be necessary to remove some part of the engine or the equipment it is used with to get at the starter unit.

If the starter is removed as a self-contained unit it will not unwind. In order to replace the rope the complete starting unit is first removed. Clamp the starter in a vise or hold it in a C-clamp as shown in Figure 121. It is much safer to hold the starter assembly in a vise instead of trying to hold it in your hands or even having someone else help. Be sure to get a good hold on the assembly so it will not slip because when the spring is put under tension, there will be a large amount of energy stored in the unit.

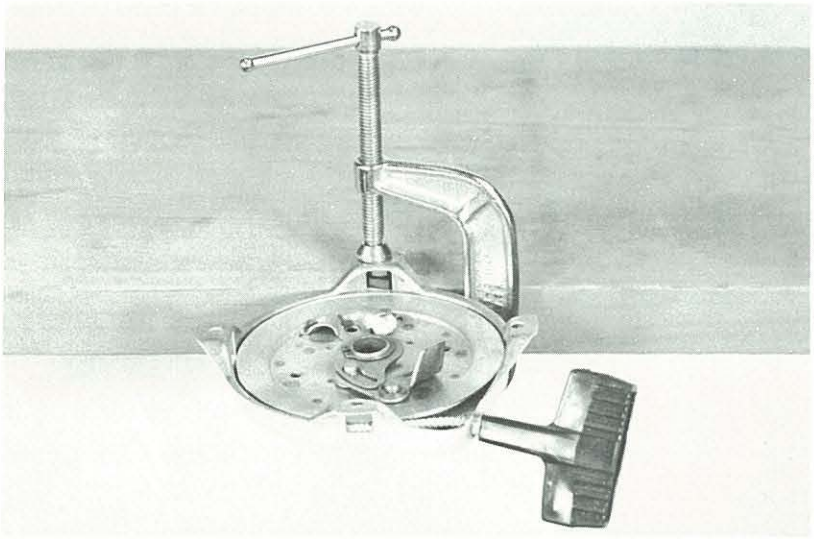
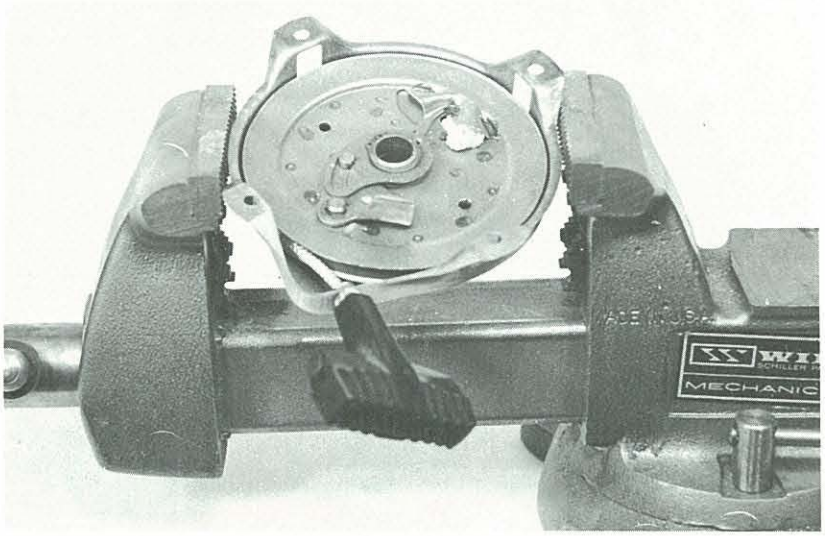


Figure 121



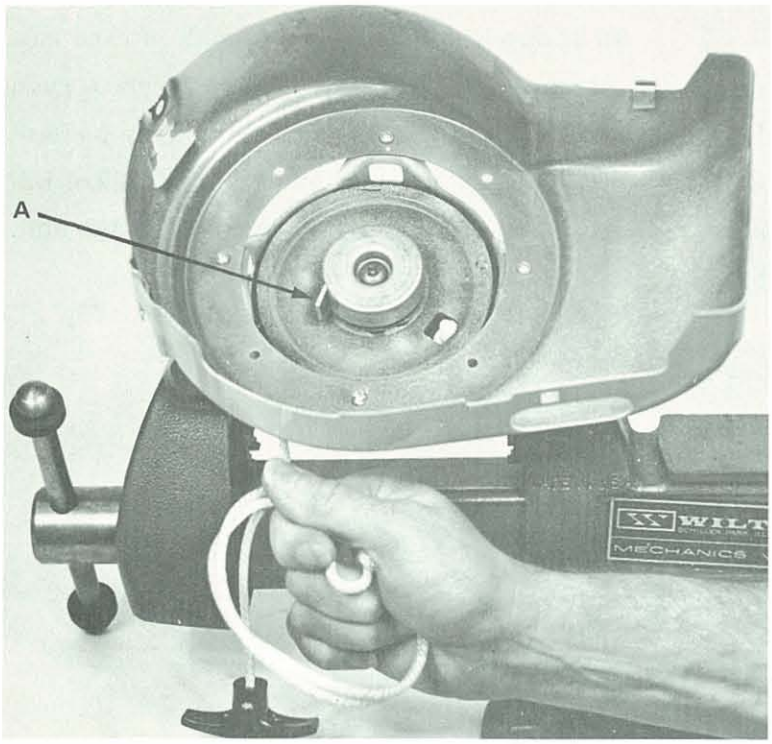


Figure 122

After you have the unit secure in the vise, pull the rope all the way out as shown in Figure 122. Notice the engaging pawl shown at A will be in the extended position.

The next step is to clamp the pulley to the housing with a pair of vise grip pliers as shown in Figure 123. Be sure to get a good grip on the pulley so it will not slip as there is a great amount of pressure exerted by the spring when the rope is all the way out.

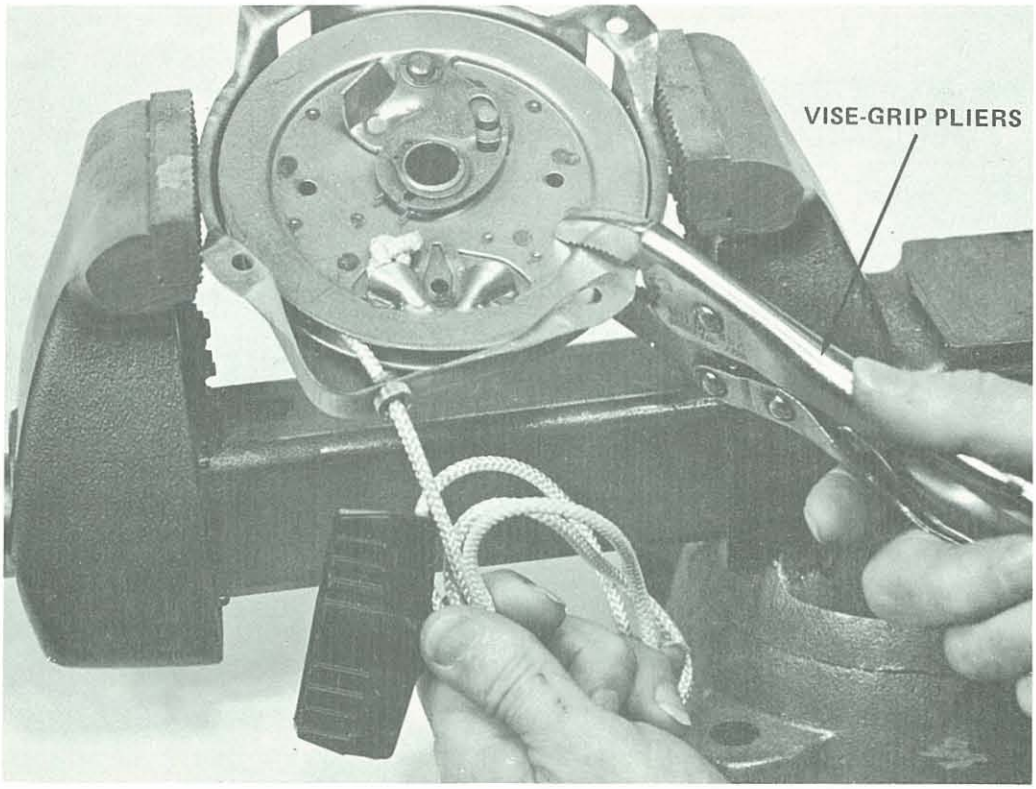


Figure 123

Cut or untie the knot next to the pulley as shown in Figure 124. It is generally easier to cut the knot than trying to untie it. The new rope should be the same length and diameter as the original one unless it was a replacement rope of the wrong length.

The length of the rope will vary with different starters but they are generally 3 to 4 feet in length and about 5/32-inch diameter. If the rope has been broken and you do not have the length it is generally safe to start with a piece 5-foot long.

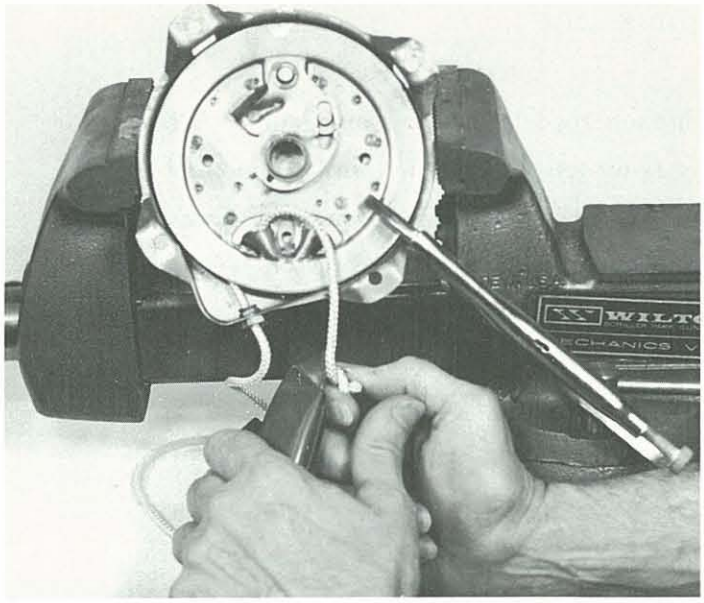


Figure 124

Singe the end of the rope if it is nylon and thread the rope through the housing eye and the pulley eye. It is sometimes helpful to hook a small piece of wire through the end of the rope to help thread it through the eye. Tie a knot in the end of the rope and pull hard so the knot will seat in the pulley.

Hold on to the rope and release the vise grip pliers. Allow the rope to wind into the pulley slowly until all spring tension is released. Pull the rope out slightly until the spring tension just begins to take place. Measure two inches of the rope from the place it comes out of the pulley housing and cut at this point.

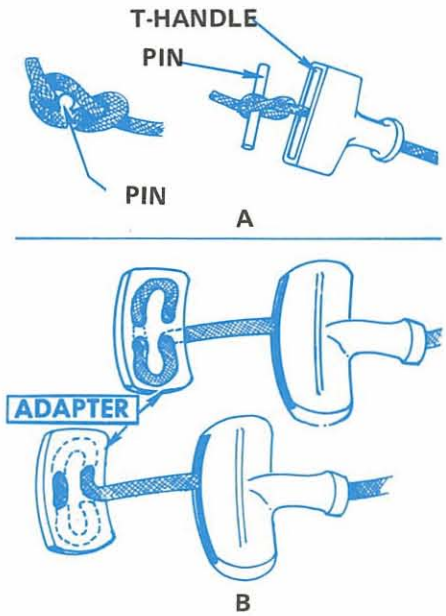
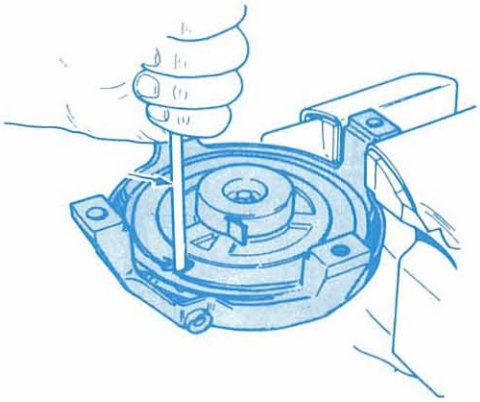


Figure 125

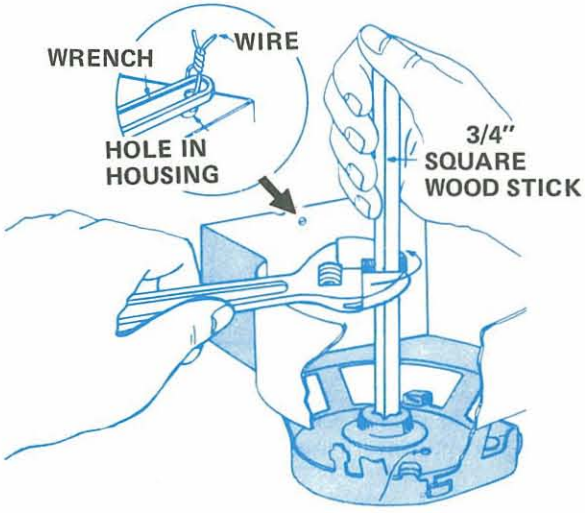
There are several methods of securing the handle to the rope other than using the knots we covered earlier. Figure 125 shows two methods very commonly used that are part of the handle design. The one shown at A uses a "figure eight" knot with a pin and the one shown at B uses an adapter insert. The rope threads into the insert and is held by a clamping action.

BROKEN ROPE

A broken rope is replaced very much the same way as we have covered on normal rope replacement except it is necessary to preload the rewind spring before replacing the rope. It would slip when holding it with vise grips. Figure 126 shows two methods of rewinding the spring for rope replacement. You can use either a screwdriver, as shown at A or if the starter is of the type shown at B you can use a piece of wood or steel stock as shown for rewinding. Often the pulley can be rewound by turning it with your hands until the spring is wound completely as far as it will go. At this point it is necessary to release one complete turn. This protects the spring from being overloaded when the rope is pulled all the way out. There should be at least one complete turn to keep the rope from being overwound and breaking when you pull the starter rope.

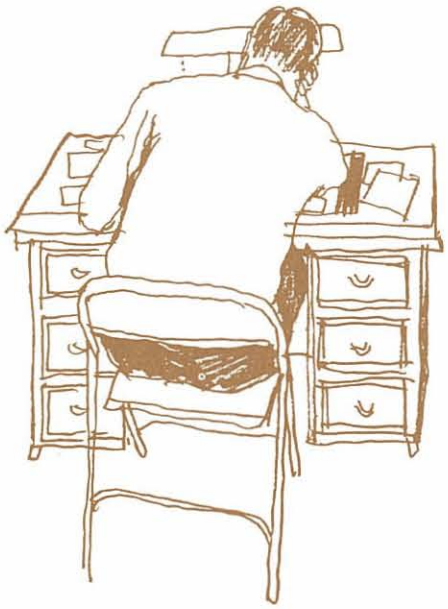


A



B

Figure 126



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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EXAMINATION ON LESSON 14
MANUAL STARTERS

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NAME _____ Student No. _____

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

100% A

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. On rope rewind starters the rewind spring is released of its tension as the rope is pulled. _____
   TRUE
   FALSE
2. On rope rewind starters the rope is rewound by a brake spring. _____
   TRUE
   FALSE
3. Side mounted starters are used on engines with _____ shafts. _____
   a. horizontal shafts
   b. vertical shafts
   c. neither of the above
4. Every starter has a driving mechanism that engages the crankshaft. _____
   TRUE
   FALSE
5. Rope rewind, windup, and electric are the three basic types of starters used on small engines. _____
   TRUE
   FALSE
6. The further the rope is pulled on a rope rewind starter, the less tension is exerted on the recoil spring. _____
   TRUE
   FALSE
7. Top mounted starters are used on most engines with vertical shafts. _____
   TRUE
   FALSE
8. Write the reference number for the following parts that are listed out for you below, as they relate to fig. 14-1.
   a. flywheel nut _____
   b. spring and keeper assembly housing _____
   c. retainer _____
   d. starter cup _____
   e. starter dog or pawl _____
   f. brake spring _____

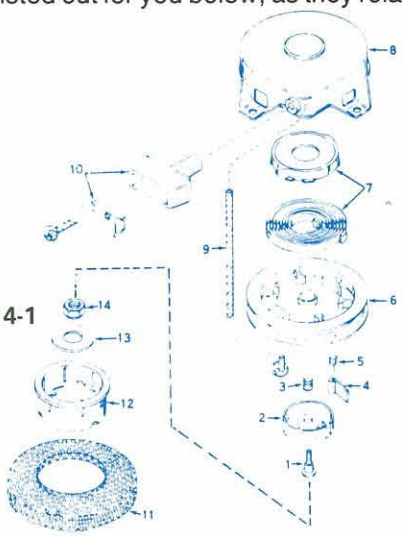


Figure 14-1

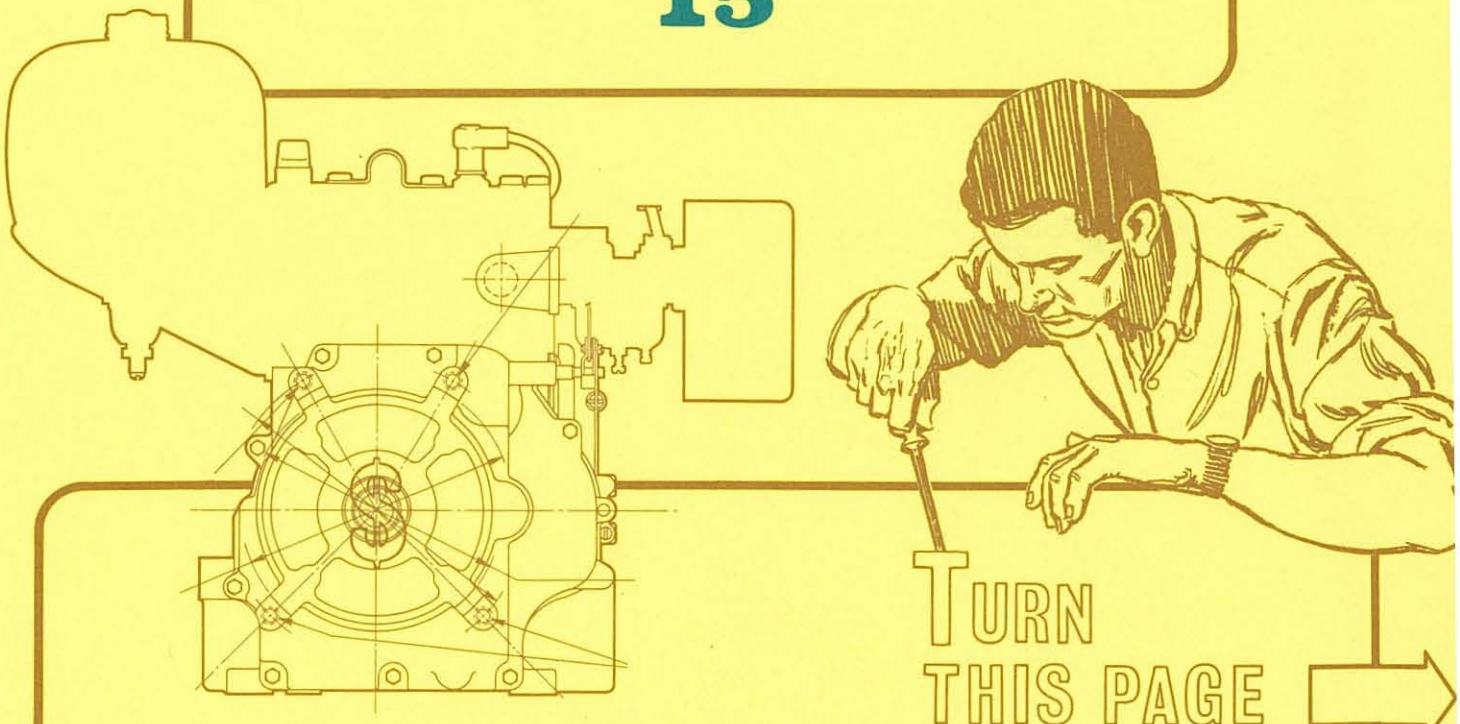
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

15



TURN THIS PAGE

...and let's find out all about -- SPRING STARTERS

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WINDUP STARTERS

Windup starters are becoming very popular on many small engines because they reduce the amount of manual effort required in starting. Figure 127 shows a typical windup starter used on many small engines. The handle shown at A folds over the top of the starter and locks in place when not in use. Lifting the handle back forms a crank that can be turned to preload the spring. After the starting spring has been preloaded the release lever shown at B can be activated to release the spring and turn the flywheel.

WINDUP STARTER

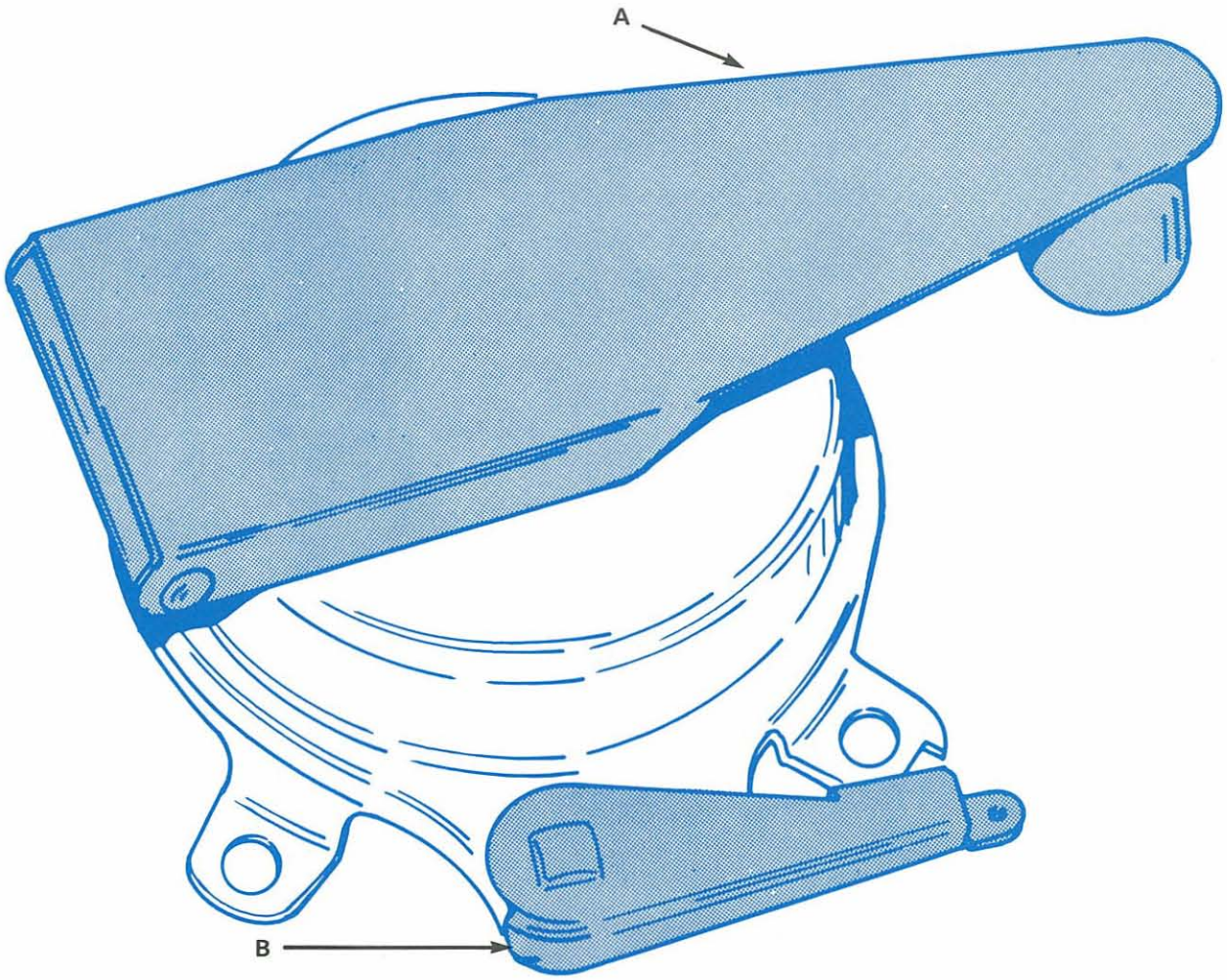
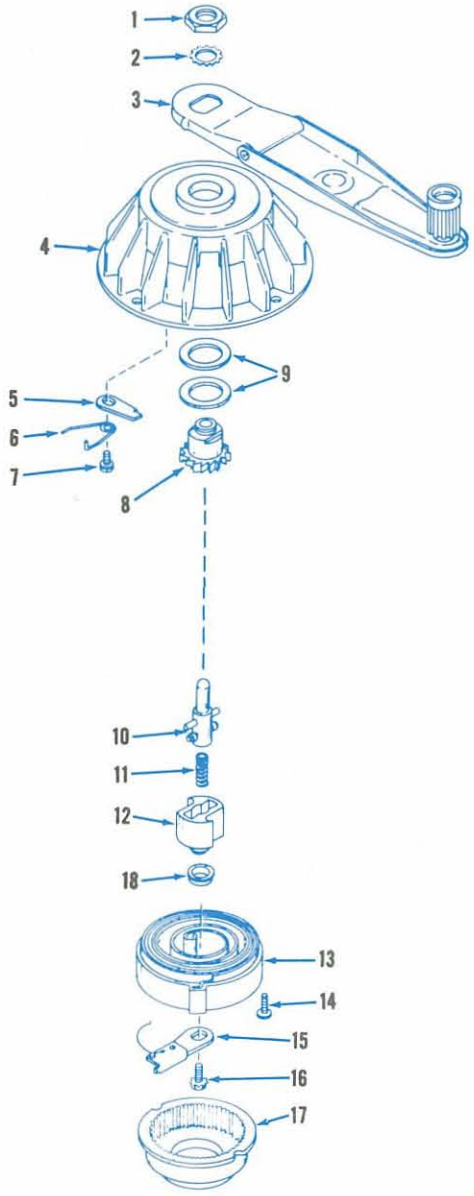


Figure 127



REFERENCE NUMBER	PART NAME
1	Nut
2	Washer
3	Handle Assy.
4	Housing, Main
5	Arm, Hub
6	Spring, Hub
7	Screw, Sems
8	Hub
9	Washer
10	Release Arm Assy.
11	Spring, Coil
12	Shaft, Drive
13	Spring & Keeper
14	Screw, Phillips
15	Pawl Assy.
16	Screw & Lockwasher
17	Cup, Starter
18	Bearing

Figure 128

Figure 128 shows an exploded view drawing and parts list of a typical windup starter. Study this drawing carefully and become familiar with the names of the parts and their relationship to each other. Very few of these starters will be the same but their basic principles will be alike. The main operating parts will generally have the same name and serve the same function. As far as engaging and disengaging the flywheel is concerned, the windup starter operates the same as all other types. Instead of pulling the rope, the starter spring is preloaded with tension. When this tension is released it engages the driving mechanism to turn the flywheel and crankshaft.

Figure 129 shows the basic parts and the functions of a typical windup starter. The crank handle, shown at A, rotates in the starter housing shown at B. The crank is connected directly to the ratchet gear shown at C. When the crank is turned, the ratchet gear turns in direct proportion to the crank. Each complete turn of the crank turns the ratchet gear one complete turn. Notice the shaft, shown at D, that the ratchet gear is attached to is connected directly to the spring at E. As the handle is turned in the direction shown by the arrows, it begins to put tension on the spring.

There must be one more part at this point to keep the ratchet handle from unwinding due to the spring tension being increased. There is a ratchet spring shown at F that engages the ratchet. This is sort of a pawl and spring combination that allows the ratchet gear to be turned in one direction only. When turning, the pressure on the handle can be released and it will not turn back in the opposite direction due to the spring tension.

The recoil spring is attached to the handle on the outside and to another shaft in the center as shown at G. This shaft is attached to the holding mechanism shown at H. As the crank handle is turned, tension is increased on the recoil spring. This, in turn, transmits energy or turning power to the shaft and holding mechanism.

At this point there has to be some form of brake or the crank would simply be turning the engine crankshaft the same as a rope starter.

WINDUP STARTER BEING WOUND

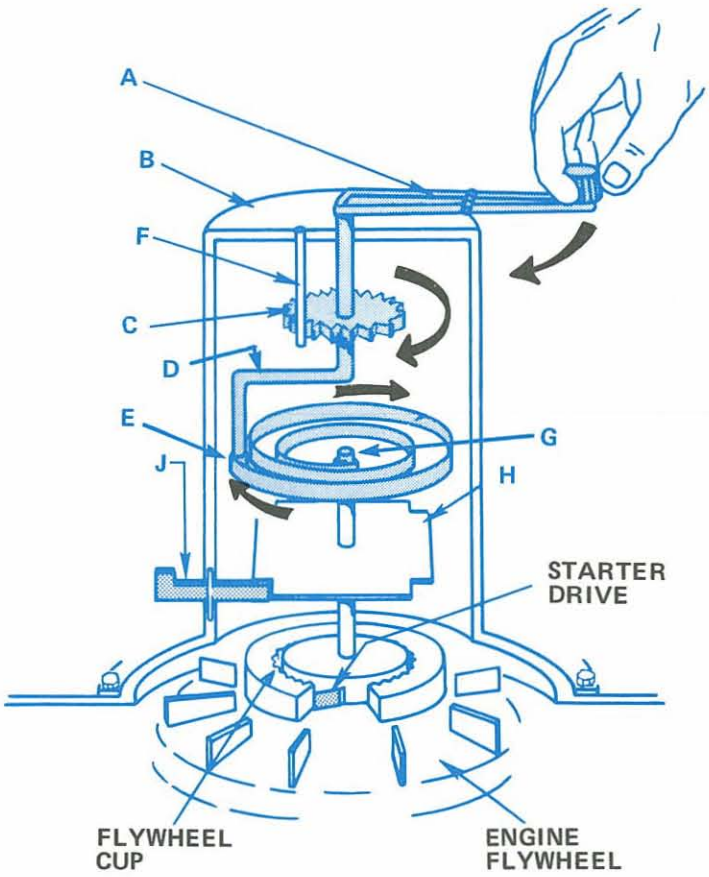


Figure 129

There is a lock or brake, shown at J, that prevents the holding mechanism from turning as the spring is brought under tension. After the spring has been brought under tension it is held in that position because the ratchet spring at F will not allow the handle to turn and the starter control lever is locked and will not allow the spring pressure to transmit power to the starting mechanism.

Figure 130 shows what happens when the starter control lever is disengaged. The control lever, shown at A, has been released from the holding mechanism, shown at B. Since this part is connected directly to the inside part of the spring and to the starter drive it begins to turn the flywheel.

One advantage of this type starter is the constant speed at which it will turn the crankshaft. There is generally enough energy stored in the spring to turn the crankshaft enough times and fast enough to get the engine started. When hand cranking, the operator will often not turn the engine at a constant speed due to the amount of pulling effort exerted on the rope. The recoil spring gives a uniform constant turning speed.

After the control lever has been disengaged, the spring returns to the unwound position as shown at C. The spring is completely without tension immediately after release of the control lever and will remain that way until the crank handle is turned to bring it under tension again.

The starting mechanism shown in Figure 129 and 130 has some variations that make it even easier to operate. This starter is set up with a one to one ratio.

WINDUP STARTER OPERATING

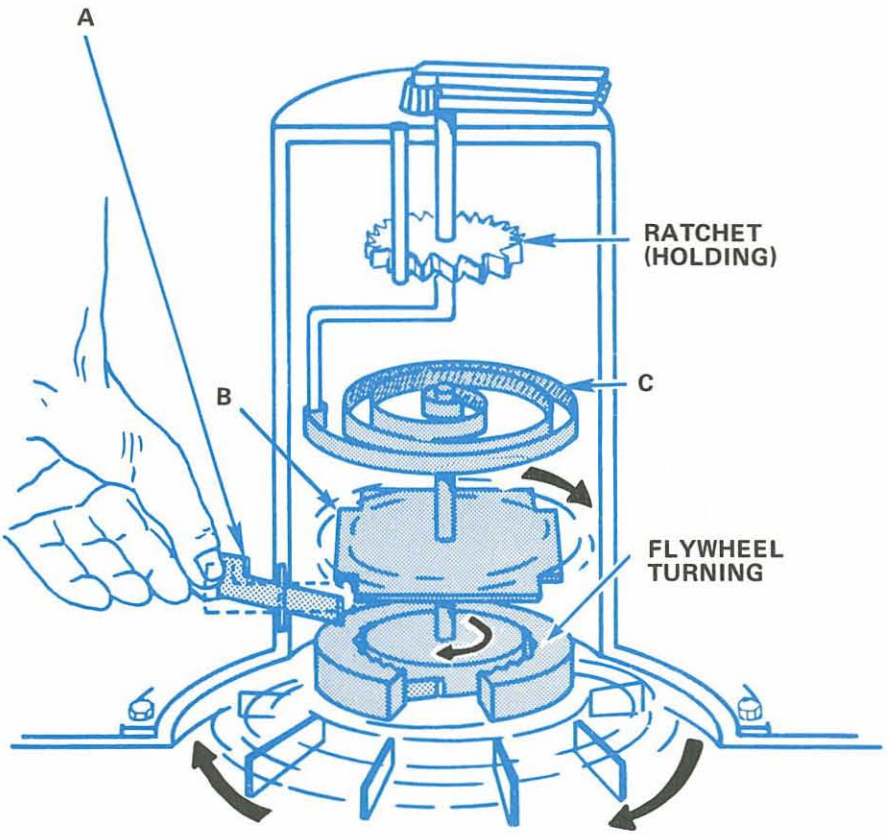


Figure 130

WINDUP STARTER WITH REDUCTION GEAR FOR EASY WINDING

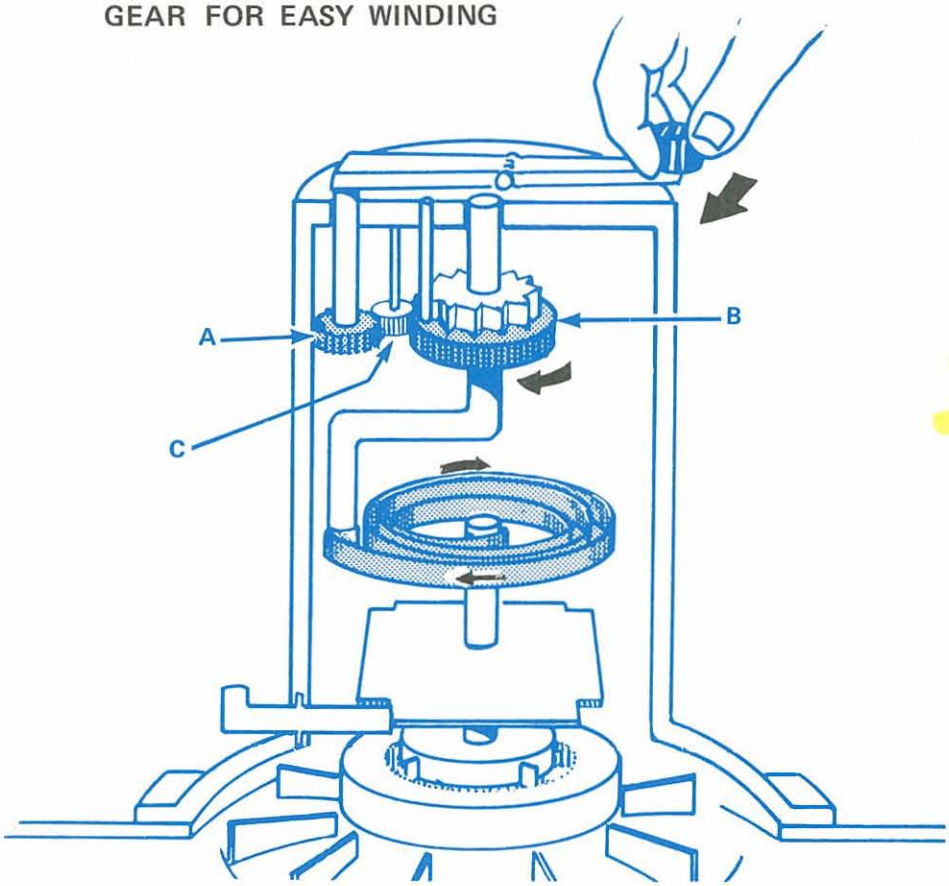


Figure 131

Figure 131 shows this same starter except a reduction drive gear has been added. The purpose of the reduction gear is to make it easier to wind the recoil spring. There is a small gear shown at A that is attached to the crank handle which, in turn, drives another small gear. This small gear drives the shaft that turns the spring under tension.

For all practical purposes we could say there is a direct relationship to the diameters of these gears and the amount of effort required to turn the driven gear shown at B. We'll cover the function of the small gear, shown at C, just a little later. If the gear on the crank handle is one inch in diameter, it would take four complete turns to turn the driven gear one complete turn. Gear drives are not actually figured on the diameter ratio like a pulley and belt drive because the number of teeth in the gear is the determining factor.

GEAR RATIO: Here is an easy way to visualize a gear ratio:

$$\frac{\text{DRIVING GEAR}}{\text{DRIVEN GEAR}} = \text{RATIO}$$

Example:

$$\frac{\text{DRIVING GEAR} = = 20 \text{ teeth} = 1}{\text{DRIVEN GEAR} = = = 40 \text{ teeth} = 2}$$

The gear ratio is 2 to 1.

Getting back to Figure 131, notice the starter handle is being turned in the same direction as the driven gear. This would not be possible without the addition of a third gear, shown at C, since each gear turns its matching gear in the opposite direction.

Figure 132 shows two gears. The drive gear is shown at A. It is turning counterclockwise or to the left. The gear at B is the driven gear and is turning clockwise or to the right.

If we wanted the driven gear to turn to the left the same as the drive gear, it would be necessary to add a third gear to reverse the rotation. This is shown in Figure 133. The drive gear at A is turning left and the driven gear at B is turning right the same as in Figure 132.

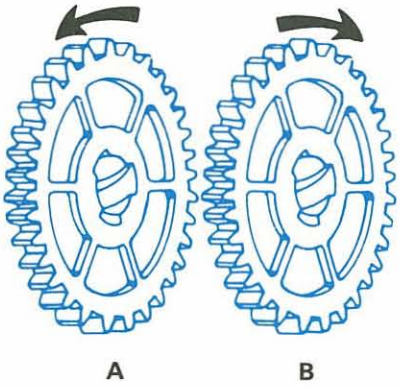


Figure 132

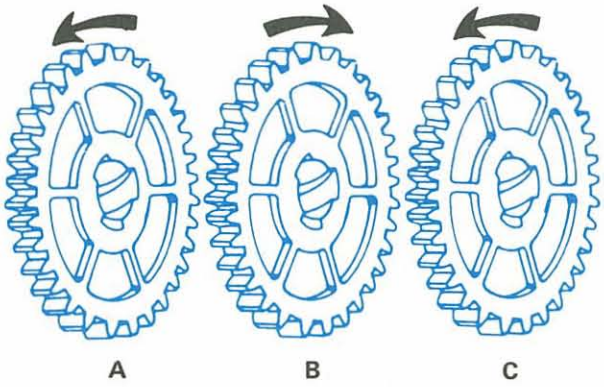


Figure 133

Now gear B becomes the drive gear and reverses the rotation of the driven gear shown at C. This gear is now turning the same direction as gear A. This does not necessarily apply to all windup starters but is simply a matter of mechanical gear functions. You will run into similar gear functions later in the course since the crankshaft and the camshaft of the engine operate on this principle with each turning in the opposite direction because the crankshaft is in direct drive with the camshaft.

We can see from these gear reductions that we can turn a small gear with little effort and create a large amount of effort with the larger gear. For every mechanical advantage there is a disadvantage. This is one of the basic laws of Physics. In this case the disadvantage is the number of extra turns involved and the time required to make the small gear make twice as many revolutions as the larger gear.

RECOIL SPRING REPLACEMENT

There are two basic types of recoil spring installations. One is a package type that is becoming very popular and is applicable to many starter designs. Figure 134 shows the related parts of the package type spring assembly. The spring and the cover plate shown at A are already factory assembled. It is in the unloaded or unstressed position before installing. Even though it may be unloaded there is still plenty of potential energy stored if the spring flies out of the housing. The center end of the spring, shown at B, locks in place with the stationary part of the housing shown at C. The outside end of the spring, shown at D, is attached to one of the lugs on the inside of the pulley at E.

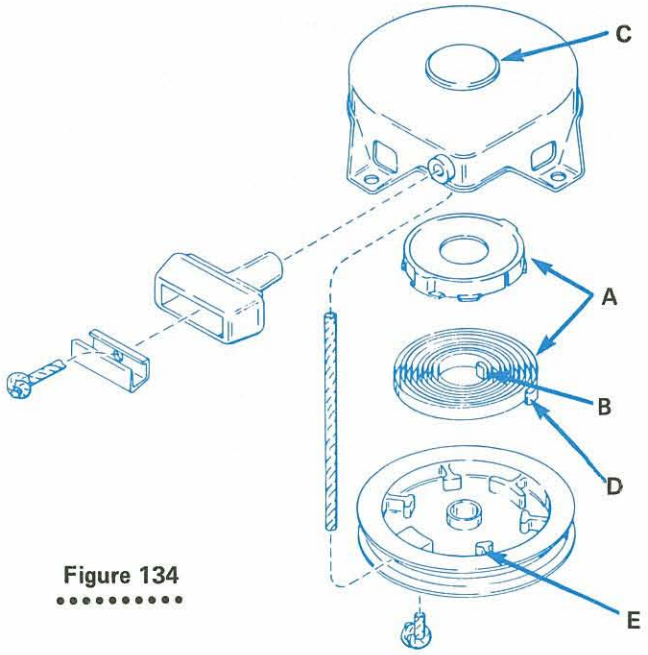


Figure 134

When the starter rope is pulled it turns pulley E. This begins to create tension on the spring. The further the rope is pulled, the more tension is put into the spring until the rope is all the way out. The spring is then under its maximum tension because the inside end is locked to the housing. With the rope all the way out and the spring under tension it will rewind the rope when it is released.

The spring cover is held in place with small clips along the side of the cover. Rotate the cover left or right just a few degrees and the entire cover and spring lift right out. You can then replace with a new assembly. It is not practical to attempt repair of these springs.

The second type recoil spring commonly used is the open type shown in Figure 135. This spring is not encased in a housing and will spring out straight when opened from its original package. This spring is wound in place by hand. The outside end of the spring, shown at A, is attached to a lug on the pulley at B. The inside end of the spring, shown at C, attaches to the hub shown at D. This part is stationary. When the starter rope is pulled the pulley begins to turn.

To replace this spring you will generally find it easier to start by first attaching it to the center lug at D. Then wind the spring around from the outside until you have it completely wound inside the pulley housing. Then attach the outside end at A to the pulley. Apply a small amount of grease to the spring and replace the cover.

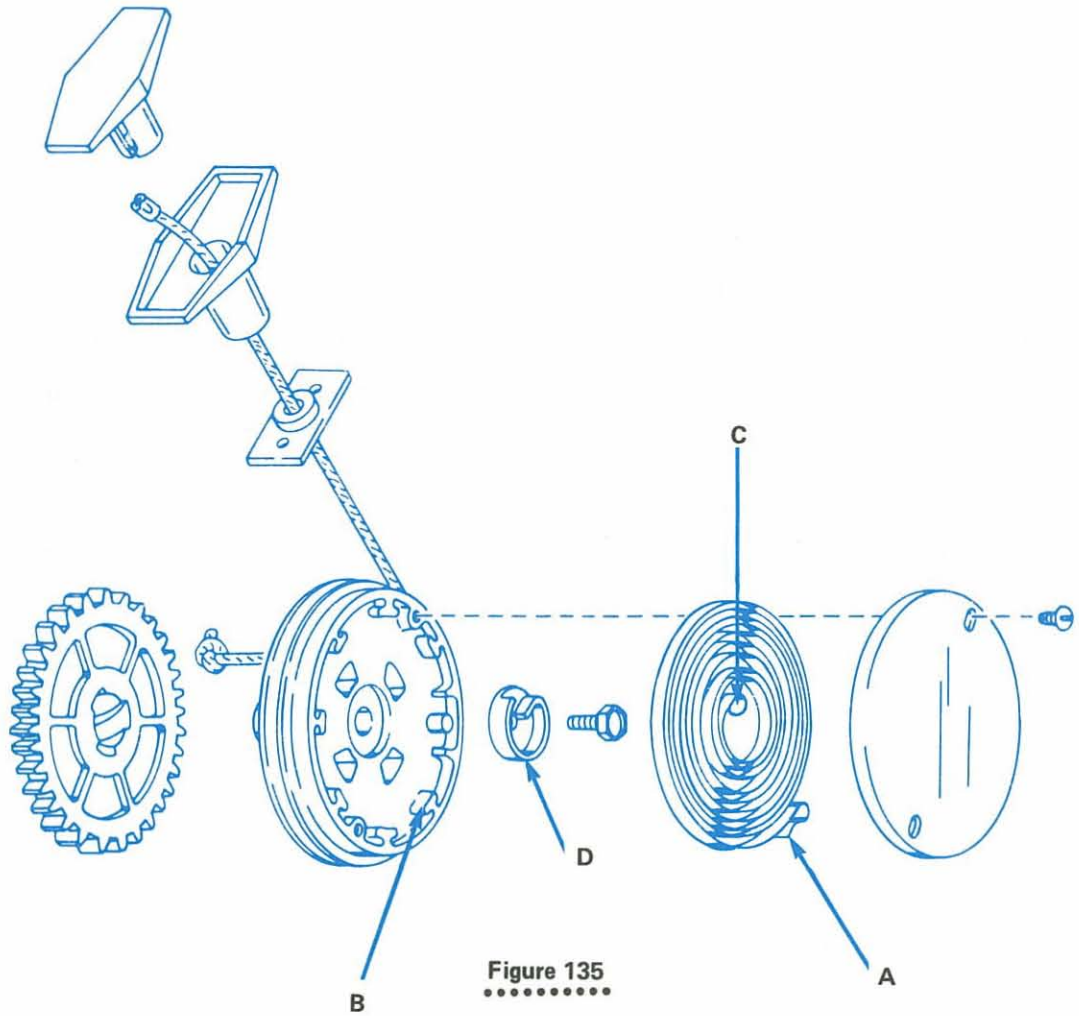
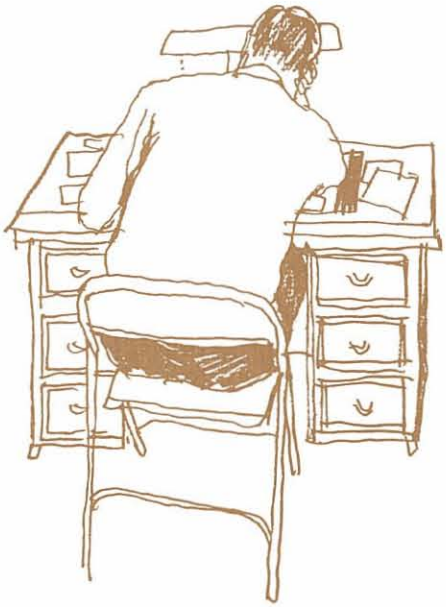


Figure 135



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Before returning your completed Exam, Remember.....

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EXAMINATION ON LESSON 15
SPRING STARTERS

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Each gear turns its matching gear in the same direction. _____
   TRUE
   FALSE

2. Through a gear reduction we can turn a small gear with less effort and create a larger amount of turning effort with the larger gear. _____
   TRUE
   FALSE

3. One advantage of the windup starter is the constant speed at which it turns the crankshaft. _____
   TRUE
   FALSE

4. When the spring tension is released on a windup starter it engages the starter mechanism to turn the flywheel and crankshaft. _____
   TRUE
   FALSE

5. If the driving gear has 50 teeth and the driven gear has 120 teeth, the gear ratio would be _____. _____
   a. 11 to 6
   b. 12 to 5
   c. 13 to 4

6. The purpose of the reduction gear in a windup starter is to make it easier to wind the recoil spring. _____
   TRUE
   FALSE

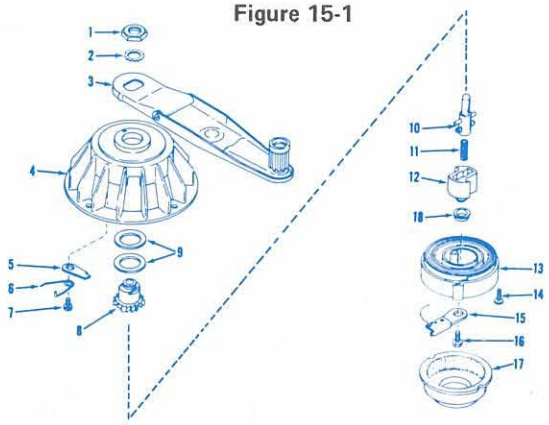
7. Windup starters are becoming very popular on many small engines because they reduce the amount of manual effort required in starting. _____
   TRUE
   FALSE

(Continued on page 2)

8. Fill in the reference numbers for the following parts that are listed below, as they pertain to the windup starter in fig. 15-1.
   a. starter cup
   b. hub arm
   c. drive shaft
   d. pawl
   e. release arm assembly

9. In fig. 15-2, the gear shown at A is turning counterclockwise. Therefore, the direction of rotation of gear D is clockwise.
   TRUE
   FALSE

Figure 15-1



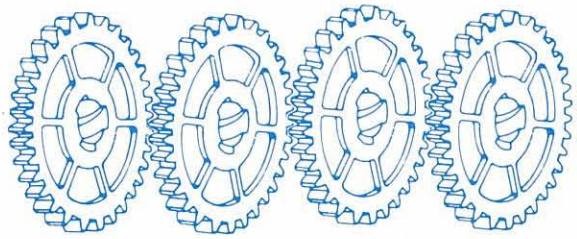


Figure 15-2

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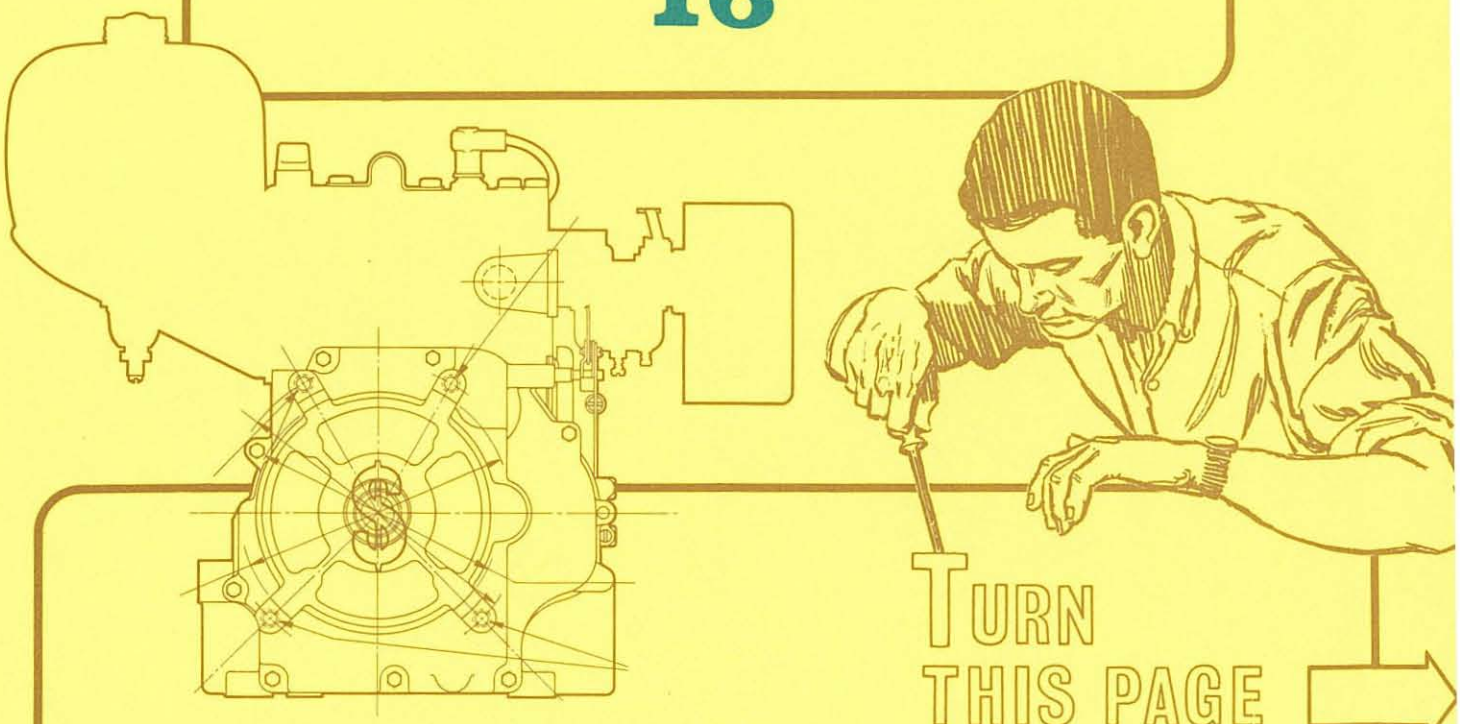

TURN THIS PAGE

...and let's find out all about --

TROUBLE SHOOTING STARTERS

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KICK STARTERS

Kick starters are basically the same design as rope-rewind starters. The main difference is the method of starting the mechanism operating. Instead of pulling the rope, the kick starter is operated by foot and sometimes by hand. This type starter is generally used on motorcycles, minibikes and other similar types of application. They are generally used on horizontal crankshaft engines.

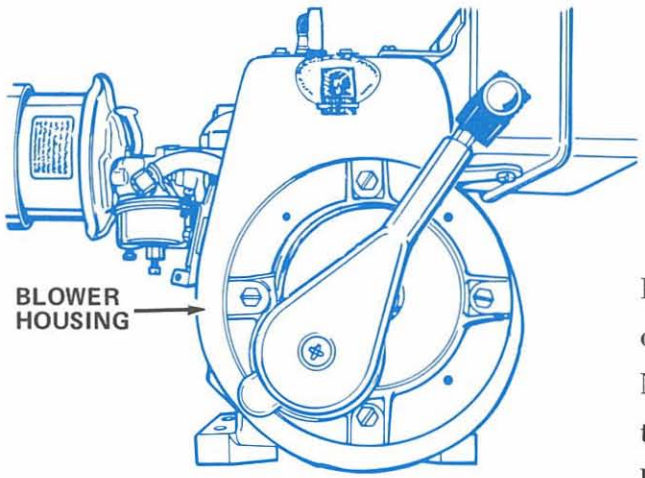


Figure 136(A)

Figure 136 shows a typical kick starter. The starter crank assembly is shown in the rest position at A. Notice the crank is set at an angle and not verticle so the operator can push straight down for starting. This kick crank is adjustable for most any position that is most convenient for the operator. It should be set so the engine is cranked when the kick crank is all the way down as shown at B. This is the ideal starting area for maximum leverage.

When the kick crank is moved from the position shown at A to the position shown at B it is the same as pulling on the rope of a rope rewind starter. The operating mechanism is very similar. There is one basic difference in this starter that is not generally incorporated in the design of the rewind starter. Kick starters generally have a slip clutch that prevents kickback. In case an engine misfired on starting it would often kick back in the opposite direction. In the case of the rope rewind starter, this would jerk the rope out of your hand. It can do this with quite a violent force. If this happened on a kick starter, it could cause injury to the operator since his foot and body weight would be on the kick start lever. In the design of the kick starter, engineers have added a small fiber disc that acts as a clutch. This disc will slip in case the engine were to misfire on starting.

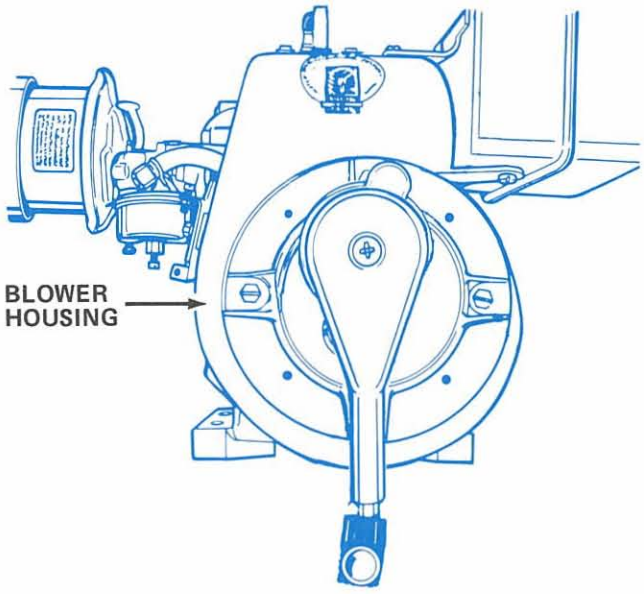


Figure 136(B)

TROUBLE SHOOTING MANUAL STARTERS

Without having a complete service manual on every starter built by all the different manufacturers, it would be impossible to give detailed instructions on the servicing and repair of the hundreds of different designs of manual starters. In any engineering design there is always more than one method that can be used to accomplish the same end result.

Within the same, almost identical, starter design there may be many variations and modifications that will take place after the parts have actually been field tested. These design changes and modifications hold true for most all areas of any engine. They are constantly being changed and improved.

The following drawings show some of the basic types of design variations in rope rewind, windup and kick starters used on small engines. You will notice there are many similarities in the problems that are encountered with these starters.

These drawings show a complete exploded view of typical starters, showing all parts, but only indicating the parts that are generally a source of trouble. These are the ones you should look for when working on or inspecting most any manual starting mechanism.

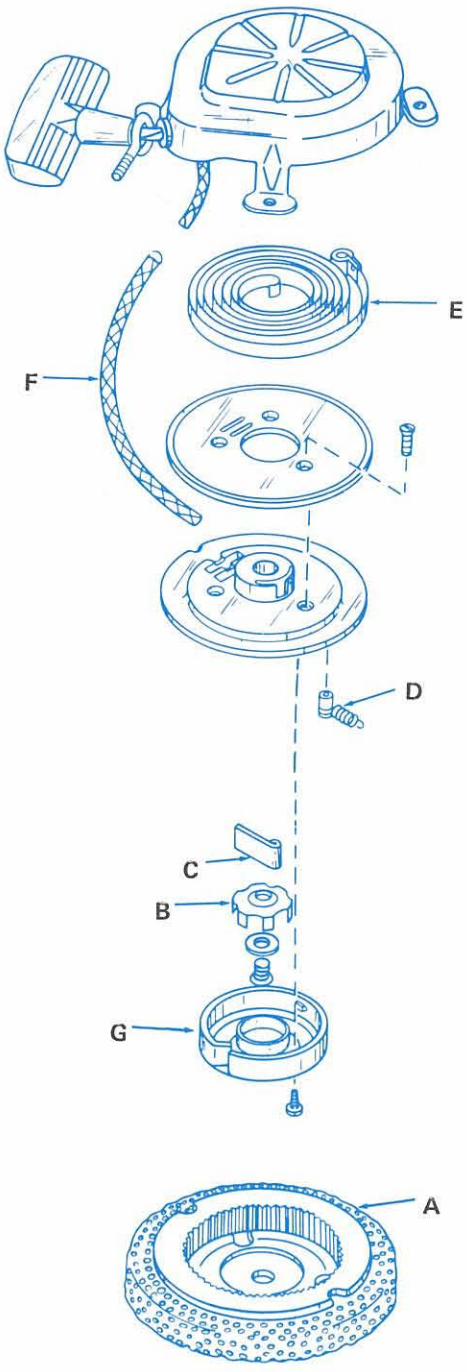


Figure 137

TROUBLE SHOOTING ROPE REWIND STARTERS

A. Worn teeth on starter cup.

B. Wear or distortion of brake shoe.

C. Marks or wear on starter dog.

D. Worn bushing or weak spring.

E. Broken or bent spring.

F. Frayed or broken rope.

G. Worn or damaged retainer.

TROUBLE SHOOTING ROPE REWIND STARTERS

A. Worn or damaged starter cup.

B. Worn or scarred washer.

C. Worn or broken centering pin.

D. Worn or damaged retainer.

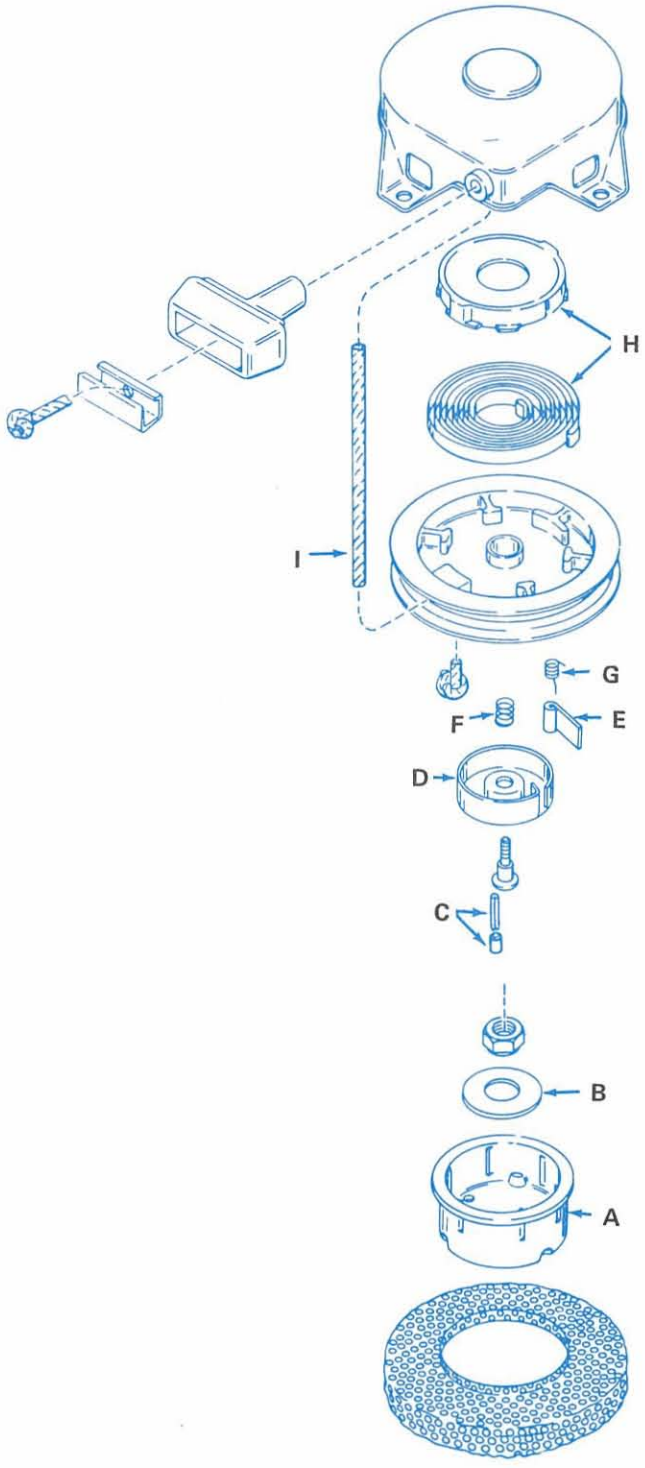
E. Marks or wear on starter dog.

F. Broken or damaged brake spring.

G. Broken or damaged starter dog spring.

H. Broken or bent spring.

I. Frayed or broken rope.



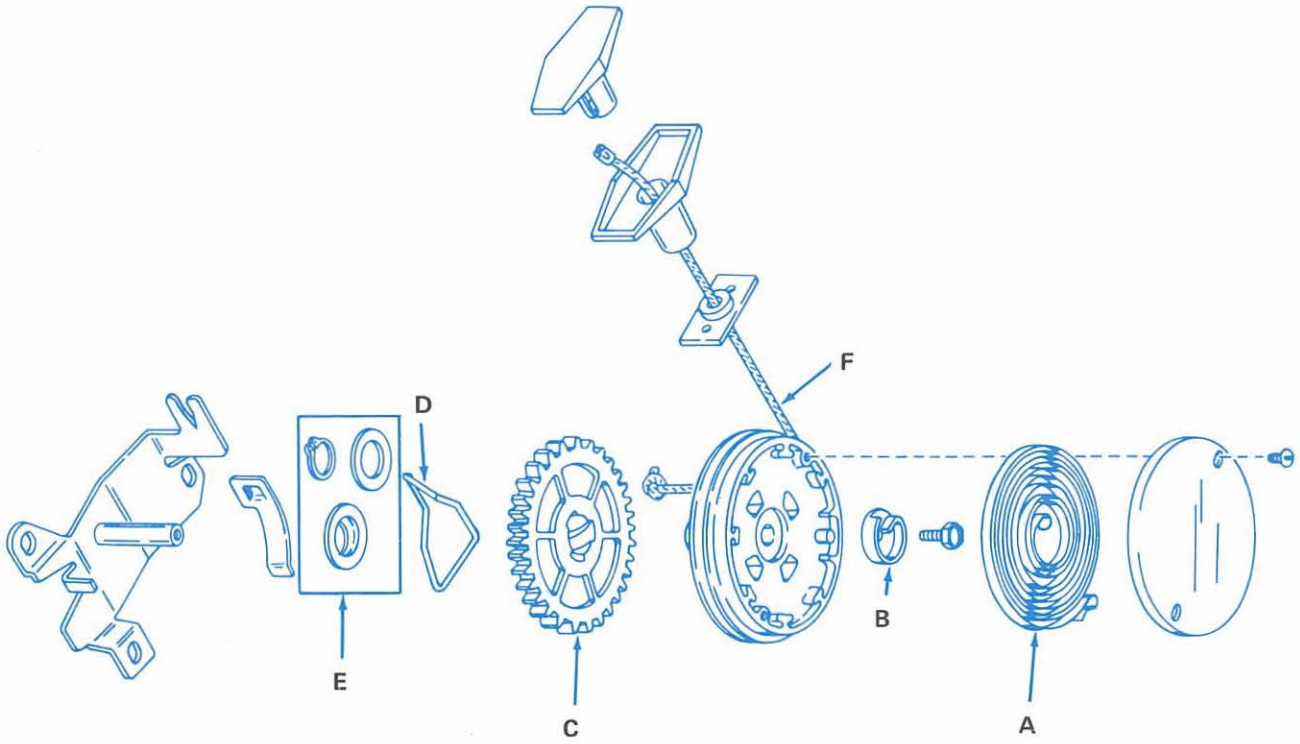


Figure 139

TROUBLE SHOOTING ROPE REWIND STARTERS

A. Weak or broken spring.

B. Weak or broken hub.

C. Cracked or chipped teeth on gear.

D. Worn or broken brake.

E. Worn or broken thrust washer and ring.

F. Frayed or broken rope.

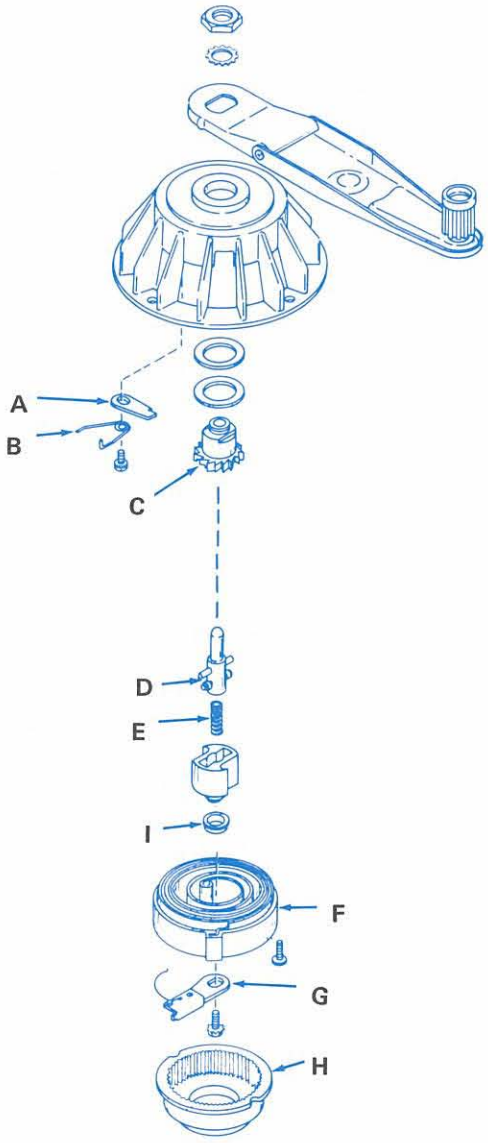


Figure 140

TROUBLE SHOOTING WINDUP STARTERS

A. Worn or bent hub arm.

B. Weak or bent hub spring.

C. Gear tooth wear on hub.

D. Worn pin on release arm assembly.

E. Broken or weak spring.

F. Broken or weak spring.

G. Worn or bent pawl.

H. Worn teeth on starter cup.

I. Worn bearing.

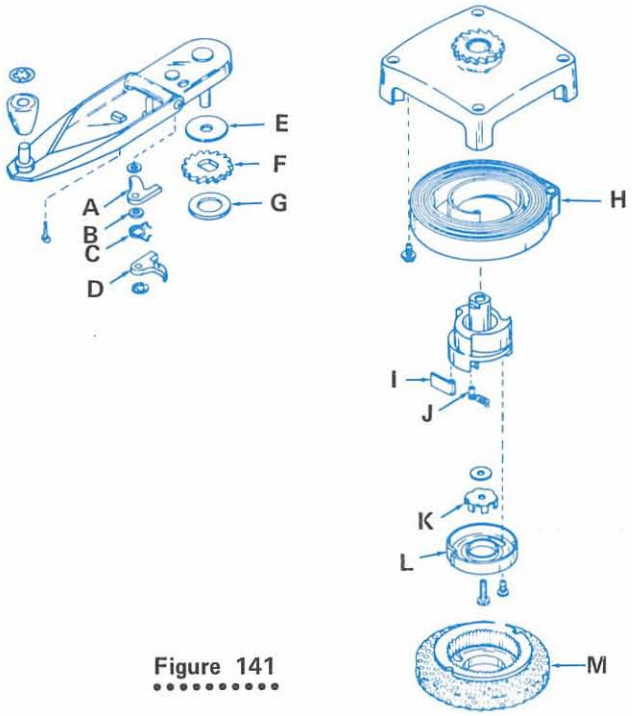


Figure 141

TROUBLE SHOOTING WINDUP STARTERS

A. Worn or broken top release dog.

B. Worn spacer.

C. Worn or broken release spring.

D. Worn release dog.

E. Worn ratchet bearing.

F. Chipped or damaged ratchet teeth.

G. Worn spacer.

H. Broken or bent spring.

I. Marks or wear on starter dog.

J. Bent or broken dog spring.

K. Wear or distortion of brake shoe.

L. Worn or damaged retainer.

M. Worn teeth on starting cup.

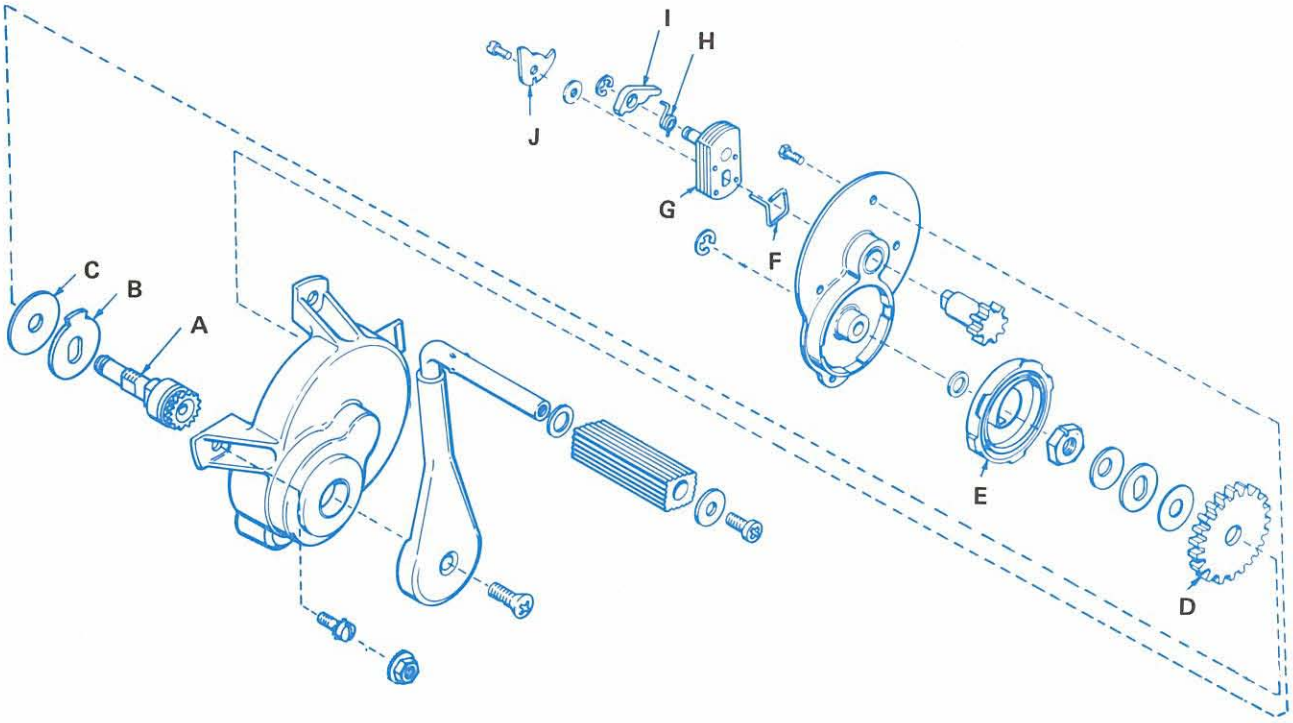


Figure 142

TROUBLE SHOOTING KICK STARTERS

A. Clutch shaft shoulder wear.

B. Clutch plate wear or scratched.

C. Clutch liner wear or scratched.

D. Gear teeth chipped or broken.

E. Spring assembly weak or broken.

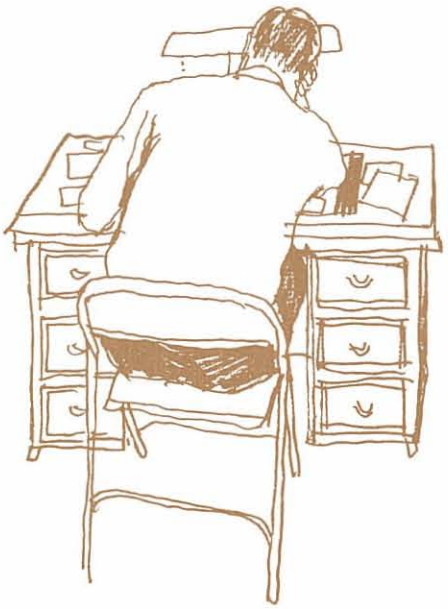
F. Brake spring broken or bent.

G. Dog plate assembly wear.

H. Dog spring broken or bent.

I. Dog wear or damaged.

J. Cam dog wear or damage.



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EXAMINATION ON LESSON 16
TROUBLE SHOOTING STARTERS

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ANSWER

1. Two parts that cause trouble with just about all windup starters are worn teeth on the starter cup and a broken or weak spring. _____
   TRUE
   FALSE

2. Some of the parts that cause trouble with rope rewind starters are _____. _____
   a. spring
   b. starter cup
   c. rope
   d. all of the above

3. Kick starters generally have a slip clutch that prevents kickback. _____
   TRUE
   FALSE

4. Kick starters generally have the same basic design as a rope rewind starter. _____
   TRUE
   FALSE

5. The intake and power are the two strokes on a four cycle engine. _____
   TRUE
   FALSE

6. Kick starters are basically the same design as rope-rewind starters. _____
   TRUE
   FALSE

7. Conduction is the term used to describe the transfer of heat through a solid material. _____
   TRUE
   FALSE

8. When fuel is combined with air, it forms a vapor that is combustible. _____
   TRUE
   FALSE

9. The three most common types of air filters used on small engines are dry, oiled, and oil bath. _____
   TRUE
   FALSE

(Continued on page 2)

10. The three basic types of carburetors used on most small engines are _____, _____, and _____.
    a. high speed, low speed, idle
    b. float, diaphragm, suction
    c. dry, oiled, oil bath

11. Energy is the ability to do work.
    TRUE
    FALSE

12. A defective gasket between the carburetor and the engine manifold will cause a lean fuel mixture.
    TRUE
    FALSE

13. The full travel of the piston in one direction is called a bore.
    TRUE
    FALSE

14. Some engines use a _____ instead of a choke valve.
    a. pressurized primer
    b. a diaphragm
    c. idle screw

15. Oil is suspended in the vapor of _____ engines.
    a. two cycle
    b. three cycle
    c. four cycle

16. The three adjustments necessary for most carburetors are the high speed mixture adjustment, low speed mixture adjustment, and the idle speed.
    TRUE
    FALSE

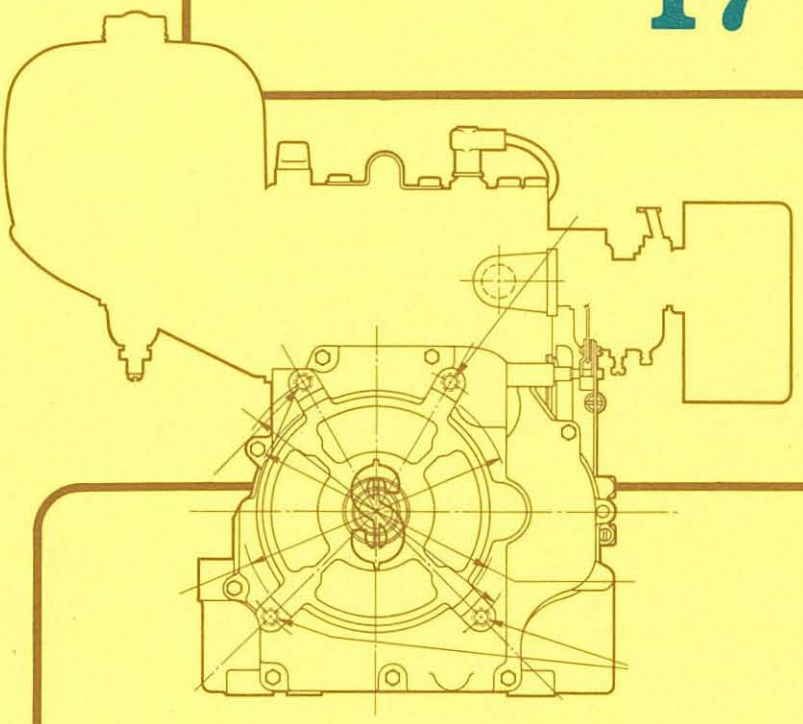
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

17



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...and let's find out all about -- **ELECTRICITY**

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FUNDAMENTALS OF ELECTRICITY

Before we get into electric starters and generators let's cover just a few of the basic theories of electricity. First, electricity will produce magnetism and magnetism will produce electricity so, you can see, they have much in common.

The service of small engines requires a basic amount of electrical knowledge. We will not attempt to give you a course in electricity but simply some of the basic fundamentals so you will be familiar with some of the electrical terms we will be using.

It will not be necessary to go into the electron, protron, and neutron theory of electricity. There are several sources of electricity, however, it will not be necessary to go into them in detail.

The entire study of electricity is based on the electron theory. The electron theory assumes that all electrical effects are due to the movement of electrons from one place to another, or that there are too few or too many electrons in one given place. In this course we'll deal only with the effect of electricity. First, let's see just what electricity and electric current is. Electricity may be defined as a form of energy, and electric current as the flow of energy through a wire or similar conductor. The flow of electricity through a wire is often compared to the flow of water through a pipe. Although it is not liquid, its method of movement is similar.

Now, we'll take up the form of electricity produced by chemical action. This type electricity is produced by cells and batteries. The basic source of electricity produced by chemical action is known as the cell. When two or more cells are combined they are called a battery.

Figure 143 shows a typical cell. This is the same type of cell used in flashlights. A is the negative plate and is the case of the flashlight cell. The metal case is zinc. B is the positive plate and is generally made of carbon. Notice it is suspended in the case and does not make direct contact with it. This carbon rod is suspended in a thick paste called the electrolyte.

The terminal, shown at C, is connected to the carbon rod. This is the positive terminal of the cell. Point D is connected to the case, and is the negative terminal of the cell. Notice, we keep calling this a cell. It does not become a battery until two or more of these cells are connected together. A cell produces 1.5 volts. A battery delivering 6 volts would contain 4 cells (1.5 x 4 = 6).

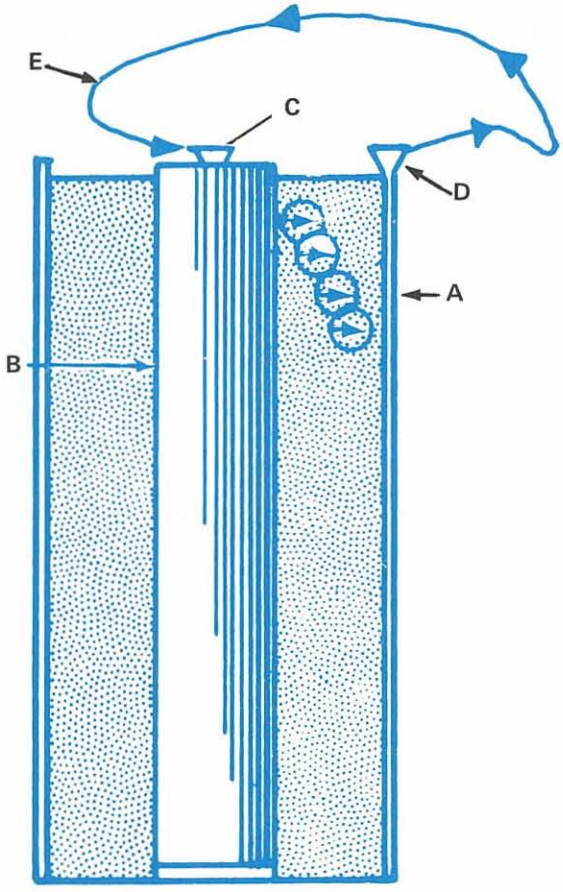


Figure 143

Now, if a wire were connected between points C and D, as shown at E, electricity would begin to flow. Electrons would begin flowing through the electrolyte paste toward the Negative Zinc Case. As long as there is a connection of a metallic object between the negative and positive terminals, the electrons will flow to the negative side. When there are no longer electrons available from the positive side, the cell will stop producing electricity. This is known as a dead cell or a dead battery.

Another method of producing electricity is mechanical. We are all familiar with a magnet. It has a north and south pole. A magnet is one of the principal parts of a mechanical device that will produce electricity. When wires are moved past a magnet, or a magnet past wires, electricity is produced. Figure 144 shows a typical bar magnet hanging on a piece of string, with the north and south poles indicated. A is a piece of copper wire. If you were to spin this magnet so the north and south poles of the magnet passed by the copper wire rapidly, you could measure the electricity that would flow through the wire. In this case there would be a very small amount, but it could be measured with a sensitive meter.

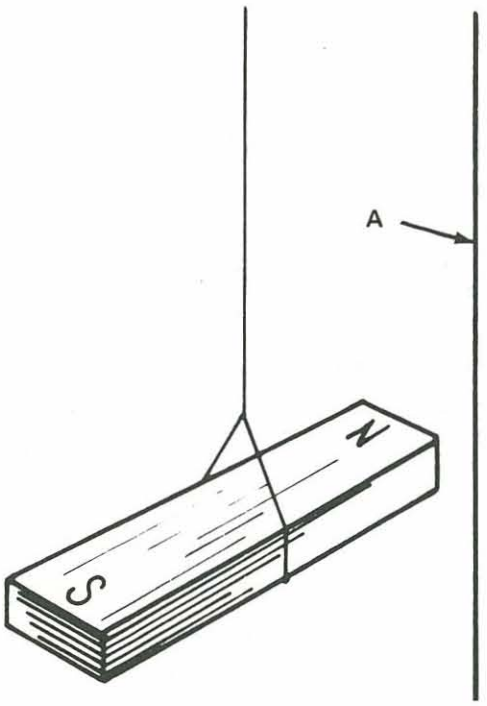


Figure 144

This is the principle of the magneto and electric starters used on small engines. This is the principle of mechanically-made electricity. An electric generator and engine starter operate on this same basic principle. They have a large group of wires called the armature. They are bound together in the center and rotate inside the magnets. These magnets are called the field. By increasing the amount of wire, the speed of the wire, and the strength of the magnet, you can increase the amount of electricity. This inside part of an electric generator is turned by some form of power, such as a gas engine.

Now, we'll take up some of the most common terms used to describe the various functions of electricity.

CONDUCTORS

A conductor is a material through which electric current will flow or move. Current may flow through liquids, gases or solids. All matter, or material has a certain amount of resistance to the flow of electricity. Some materials permit this flow more easily than others. Silver is considered one of the best. Next in line of conductivity are tin and lead. These are followed by copper which is the most commonly used because of its availability and price.

INSULATORS

Insulators are just the opposite from conductors. They have a high resistance to the flow of current. Some materials will transmit a small amount of current while others will transmit almost no current at all. Some examples of good insulators used in electrical circuits are porcelain, rubber and glass.

AMPERE

Ampere is the unit of measure used to designate the amount of current that flows through a conductor in a given time. This can be compared to water. If it takes a 1/4-inch water pipe one minute to fill a gallon bucket, we say it is flowing at a rate of one gallon per minute.

Often it is necessary to work in units considerably less than a full ampere. We can divide the ampere into units the same as we can divide a gallon into 4 quarts, and a quart into 2 pints. One thousand milliamperes equals one ampere, and one million microamperes equals one ampere. We can measure this phase of electric current with a meter. This meter is called the Ampmeter.

VOLTS

Volts are another unit of measure to designate the force of current. Volts can also be compared to water. If you had two water tanks as shown in Figure 145, both the same diameter, and you opened the valve at the bottom, you would have more pressure on one of the tanks. If tank A was 50 feet high, and tank B was only 25 feet high, the weight of the water would cause more pressure at the bottom of tank A. Volts can also be measured with a meter called the Voltmeter.

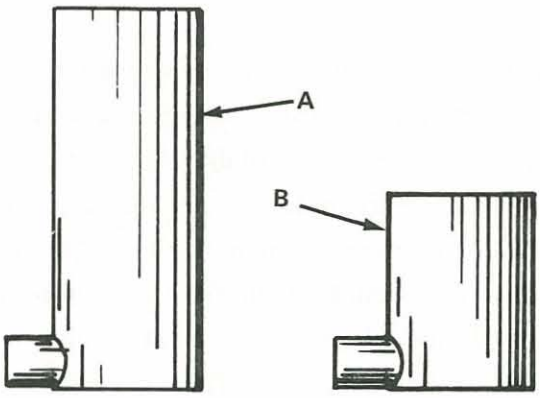


Figure 145

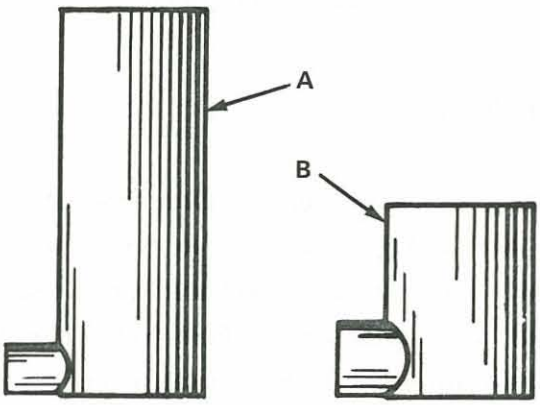


Figure 146

RESISTANCE, RESISTORS, AND OHMS

The opposition to the flow of current is not the same in all materials. Every material has some opposition to the flow of current, some small, some large. This opposition to the flow of current is called resistance. Consider again, the comparison between electricity and water. Figure 146 shows the same two water towers. Only tower A has a very small opening at the bottom and tower B has a larger opening. The opening in tower A will have a very large resistance to letting the water drain out. Tower B will have much less resistance, because of the larger opening. Tower A wants to restrain the water from flowing through the opening. The same is true with materials carrying electricity. Some of them want to restrain the flow and others want to let it pass freely. By now, you are probably beginning to see the relationship between Resistance, Amperes and Volts. The easiest way to understand this in general terms, without going into the reasons behind the electrical theory is that with a given voltage supply, as the resistance increases the amperage decreases.

The term RESISTOR is used for a material that is purposely put into an electrical circuit to resist the flow of current. Now we can measure resistance, the same as volts and amps, with a meter. The unit of measurement for measuring resistance is called the OHM. The meter used to measure ohms is called the Ohmmeter. Often in drawings of electric circuits you will see symbols as shown in Figure 147. These 4 symbols indicate resistance of one form or another.

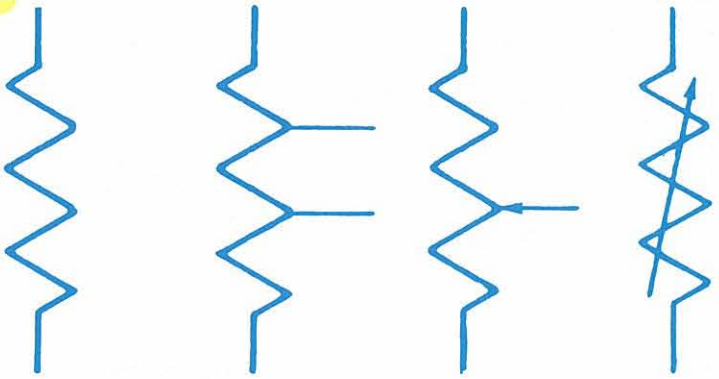


Figure 147

ELECTRICAL CIRCUITS

We have mentioned the word circuit several times so far. Let's see just what a circuit is. Basically there are four different types of circuits; closed, open, series and parallel. Figure 148 shows a typical example of a closed circuit. The cell shown is connected to a lamp. We have already learned that current flows from negative to positive. A is the negative terminal of the cell. The wire shown at B is connected to one terminal of the lamp. Since current flows from negative to positive, the current will flow through the bulb and out the other wire, shown at C. The wire at C is connected to the positive terminal of the cell. This makes a closed circuit. The current is flowing from point A through the bulb and out the other wire back to the positive terminal of the cell.

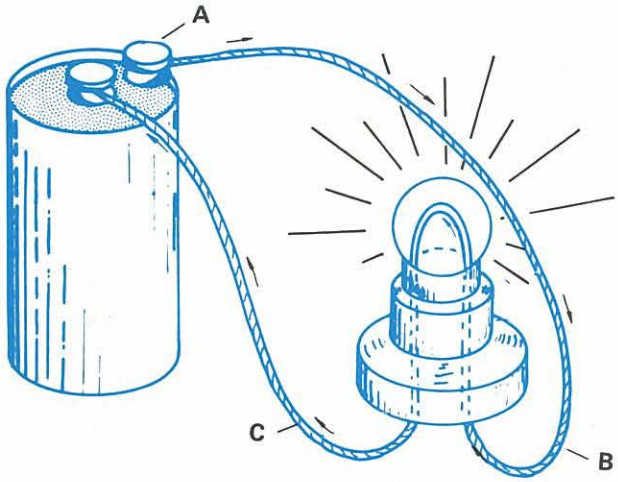


Figure 148

An open circuit would look like Figure 149. Notice both drawings look the same, except the wire shown at A has been cut. The current starts to flow out the negative terminal at B and stops because it cannot make the complete circuit. One thing to remember is that an electric current must always come back to its starting point. It's like a circle. It has no starting or stopping point.

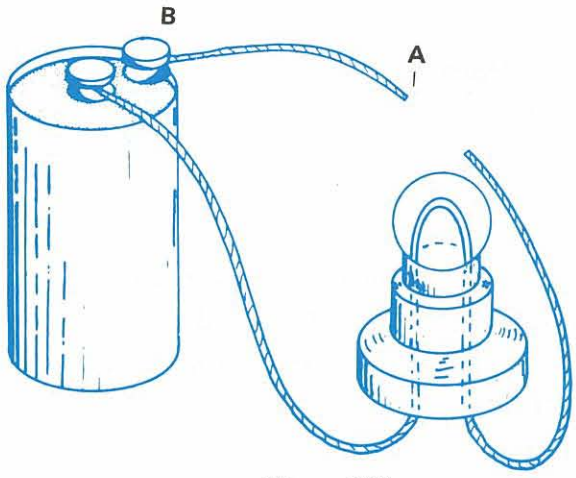


Figure 149

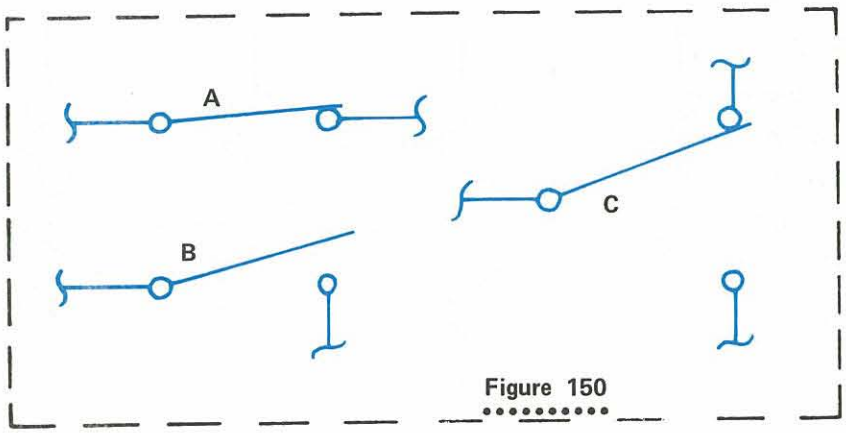


Figure 150

Obviously we cannot be cutting wires or disconnecting them from the cell to start and stop the flow of current so we use switches to perform this operation. In electrical drawings you will often see symbols like the one shown in Figure 150. A shows the switch in the closed position. Current will flow through the switch and make a closed circuit. B shows the same switch in the open position. Current will not pass through this switch. You will have an open circuit. C shows another type of switch, used to divert the current flow from one circuit to another.

SERIES CIRCUIT

There are two kinds of circuits used in most electrical equipment. First, we'll take up the series circuit. Remember earlier when we studied the cell and battery, we learned a battery was constructed of two or more cells. Each cell produces 1.5 volts. When we connect two cells in series we produce a battery delivering 3 volts. If we continue adding cells and connecting them in series, we add 1.5 volts to the battery output with each cell we add to the series.

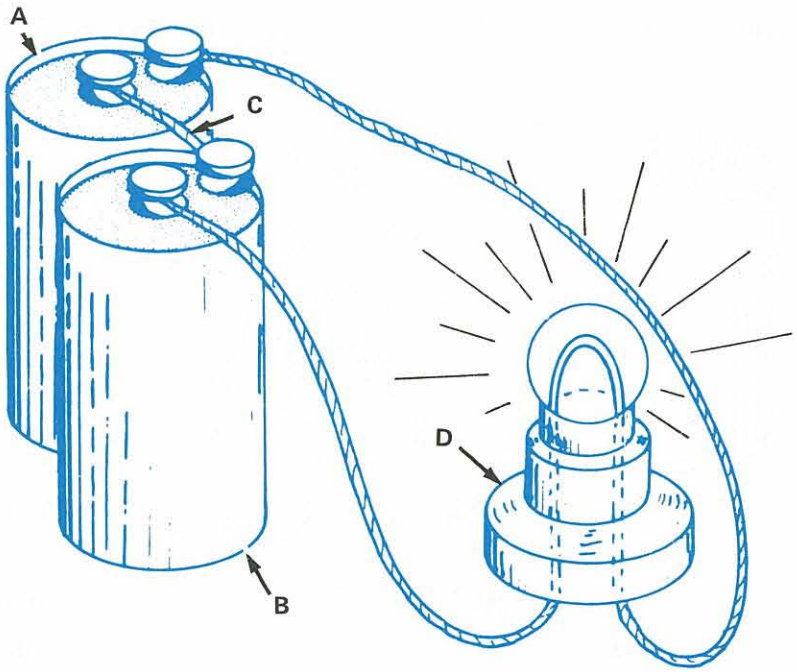


Figure 151

Figure 151 shows two cells connected in series. Notice the positive and negative terminals of these cells. The positive terminal of cell A is connected to the negative terminal of cell B by the wire shown at C. The negative terminal of A is connected to one terminal of a lamp or other appliance. This type of connection makes a battery capable of delivering 3 volts. If you were to connect a 3-volt lamp bulb in the lamp base shown at D, it would light.

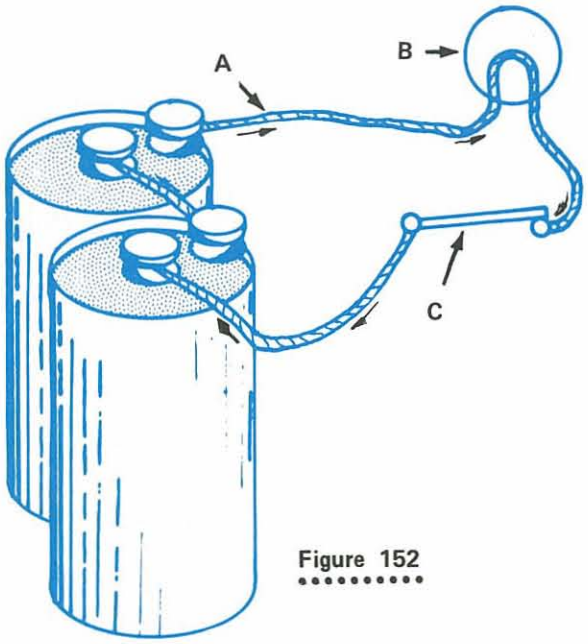


Figure 152

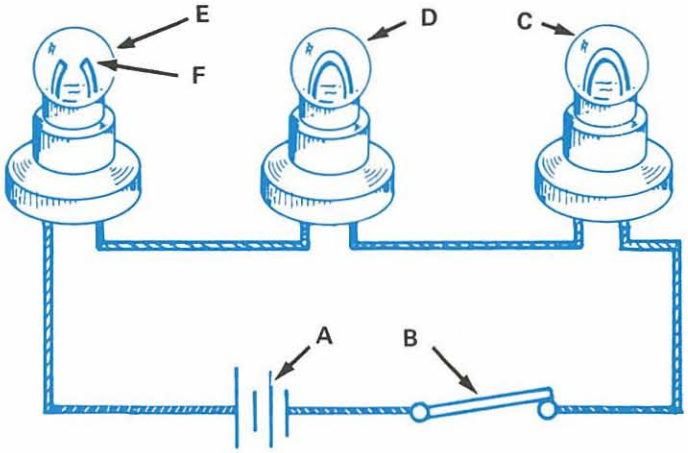


Figure 153

Now, let's look at a series circuit, including a lamp and switch, all connected in series. See Figure 152. We have two cells connected so they make a 3-volt battery. The current starts flowing from the negative side of the battery in the wire shown at A. It flows through the lamp shown at B. The symbol shown at B is used in electrical drawings to indicate a light bulb or lamp. The current flows from the lamp to the switch shown at C, through the switch, and back to the positive terminal of the battery.

Now, let's look at a series circuit with more than one lamp in the series. See Figure 153. Like most other parts of an electrical system, the battery also has a symbol. The symbol of the battery is shown at A. The left side is positive and the right side is negative. The current starts from the negative side of the battery and flows through the switch at B. From there it flows to the lamp shown at C, and on through the lamp to the next lamp at D. It keeps on going in the same direction until it gets to lamp E. This lamp is burned out as shown at point F.

The current has an open circuit at this point and cannot go back to the positive terminal of the battery. Because of this open circuit, the current cannot make a continuous circle, and no current will flow. When any one of these bulbs is burned out, or the switch is open, none of the bulbs will light. This is the type circuit used on some of the lower-priced Christmas tree sets. If you replace the bulb at E, all three of them will light, since the circuit can continue on to the positive terminal of the battery.

SHORT CIRCUIT

In order for a usable amount of current to flow in a series circuit, it must flow through something with a resistance. We learned earlier that electricity is a form of energy. This energy must be dissipated in one form or another. A circuit not having some built-in form of resistance to dissipate the energy, is called a short circuit.

If a short piece of copper wire is connected to the two terminals of a battery, it will become hot very quick. If a wire is very long it will be able to dissipate the energy and it will not become hot. The longer the wire the higher the resistance. The resistance built into a lamp allows it to dissipate the energy in the form of light and heat.

Current will follow the path of least resistance. Figure 154 shows a typical circuit with one lamp connected to a battery. There is one thing different in this circuit. Notice the short circuit shown at A. Since current will follow the path of least resistance, it will follow the path of the arrows shown in the drawing. The piece of wire causing the short circuit has less resistance than the lamp. Since there is no resistance in this circuit except the wire, there will be a tendency for the wire to get very hot. If this short circuit were removed, the current would pass through the lamp and make a complete circuit. The lamp would absorb the required current.

When a short circuit occurs, we eliminate the possibility of the wire becoming excessively hot by the presence of a fuse in the circuit. A fuse is constructed of a conductor that will melt when it becomes slightly hot. When a short circuit exists the fuse will melt and make an open circuit. This stops the flow of current, since it cannot make the complete path from negative through the circuit and back to positive.

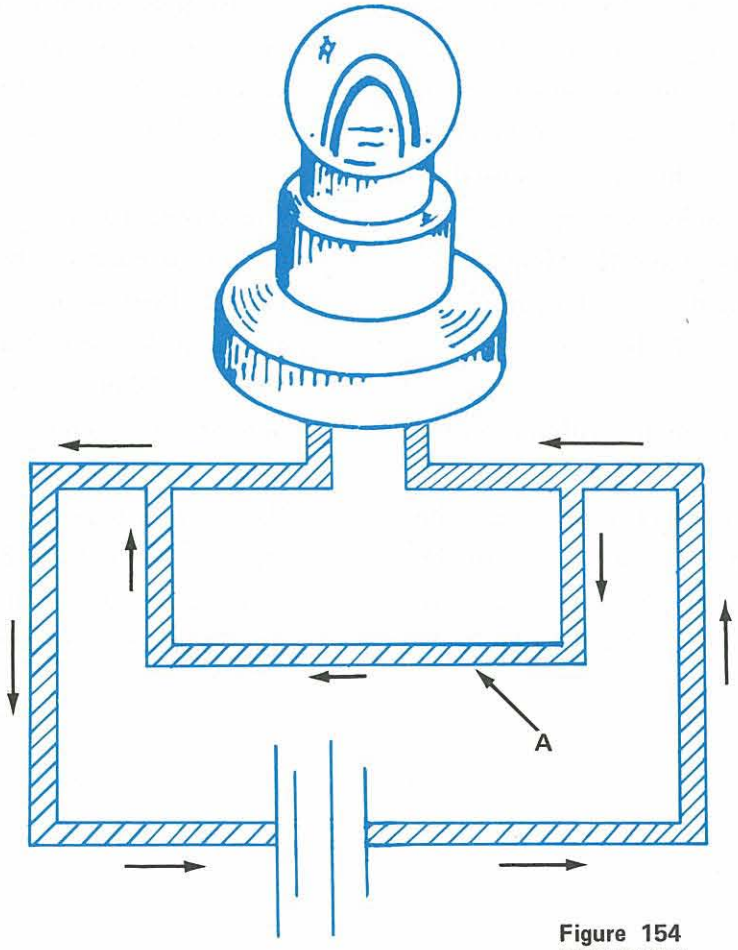


Figure 154

Now let's review the layout of a typical series circuit. Figure 155 shows a series circuit set up with a lamp, radio, electric clock and a fuse, all connected in series. Notice the current leaves the negative side of the battery and goes to the lamp. It goes in one side of the lamp socket, through the bulb, and out the other wire. From there it goes in one wire of the radio, through the radio, and out the other wire. It then goes through the clock.

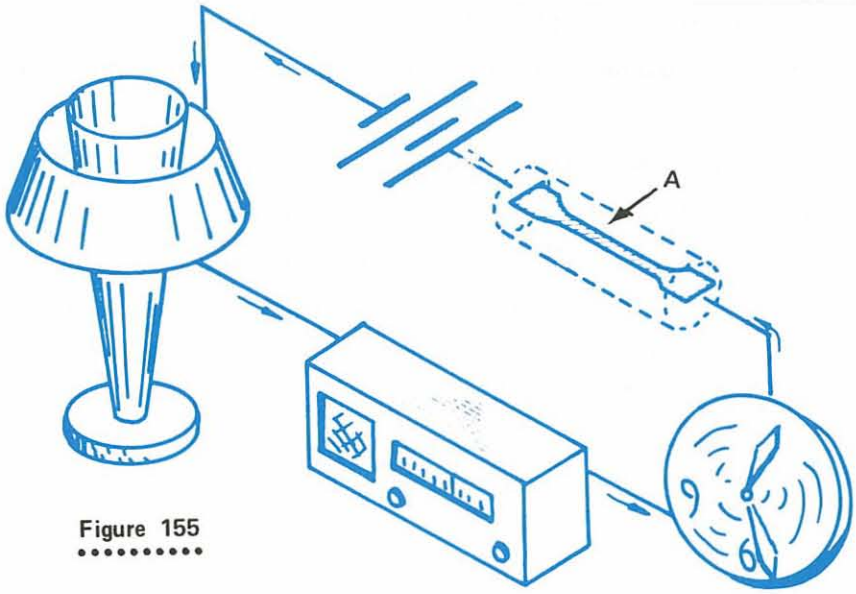


Figure 155

The current travels around the wire to the fuse shown at A. It goes through the fuse, and back to the positive side of the battery. If this circuit were broken, or opened in any place, all the appliances would stop working. If the light bulb burned out, the radio and clock would stop.

In order for this circuit to operate, it would be necessary to have both the lamp and radio switch in the on position. Turning off the lamp or radio would be the same as an open circuit. As we learned earlier, if a short were introduced into the circuit, it would create heat. This heat could damage the appliance, so we have a fuse in the circuit. When a small amount of heat is introduced into the circuit the fuse will melt and stop the entire circuit, because the current cannot return to the positive side of the battery.

PARALLEL CIRCUITS

We have learned how cells are connected in series to form a battery. We connected the negative terminal of one cell to the positive terminal of another, to increase the voltage and make it a battery. Each time we added a cell, we increased the voltage by 1.5 volts.

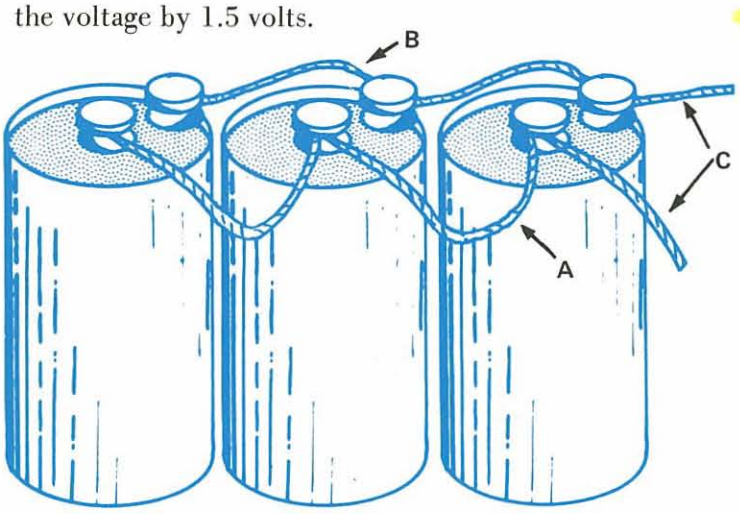


Figure 156

We can also connect cells in parallel. When we connect cells in parallel, we do not increase the voltage. The voltage will remain the same; however, the life of the battery will increase approximately by the number of the cells added. Three cells connected in parallel should last approximately 3 times as long as one cell. Figure 156 shows three cells connected in parallel to form a 1.5 volt battery.

Notice the wire A is connected to the positive terminal of the first cell and goes to the positive terminal of the other cell. From there it goes to the positive terminal of the third cell. Wire B is connected to the negative terminal of each battery. The two wires shown at C would produce 1.5 volts.

Now, let's look at a typical parallel circuit. Let's use the same appliances used in Figure 155 only we'll connect them in parallel. Figure 157 shows the lamp, radio, clock and the fuse connected in a parallel circuit.

Starting from the negative terminal of the battery you can follow the arrows and see the flow of current. When current reaches point A, part of it will turn and go into one side of the lamp. It will go through the bulb and out the other wire of the lamp. It will then return to the positive side of the line at point B. From there it goes to the fuse, shown at C. In addition to the current turning at point A and going to the lamp, it will also go straight to point D and through the radio. It will come out the other side of the radio, and back to the positive side of the battery. It will follow the path shown by the arrows. In addition to turning at A and D, current will also go on to the clock and enter at E. As it comes out of the clock it will return to the positive terminal.

Notice how each individual appliance is actually connected in series; however, when they are all connected as shown, they are in parallel. If the circuit were broken at point F, the clock would stop but it would not effect the lamp or the radio, since both of them still have a path for the current to flow back to the positive side.

If the circuit were broken at point G, both the radio and the clock would stop, however, the lamp would still burn. It has a path for the current to flow back to the positive side. Now notice the location of the fuse at C. This fuse is connected in series, so if it burns out the entire circuit stops. The fuse is always placed as near to the current source as possible. In this kind of circuit you can turn any of the appliances off and the others will still work.

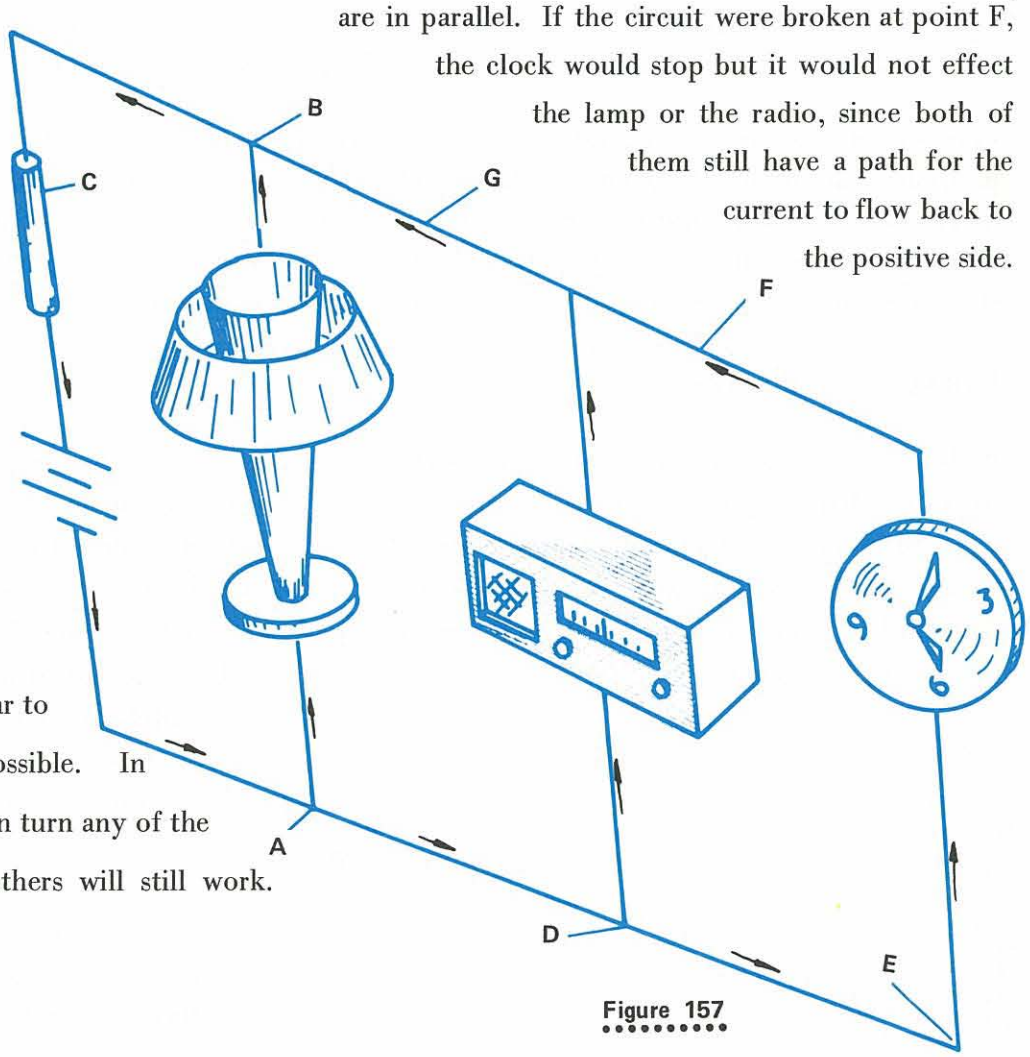


Figure 157

SERIES-PARALLEL CIRCUITS

Series-parallel circuits are actually just a combination of the two circuits we have already studied. These circuits are used in many electrical applications and consist of three or more forms of resistance in the same circuit. Figure 158 shows a combination circuit with one lamp in series and two in parallel. As the current flows from the negative side it first goes through lamp A. Then it goes to point B where it flows through both lamps C and D. It comes out at point E, and continues on to the positive side. Now if the bulb in the lamp A were removed or burned out, the entire system would go out, since the current flow would stop at this point.

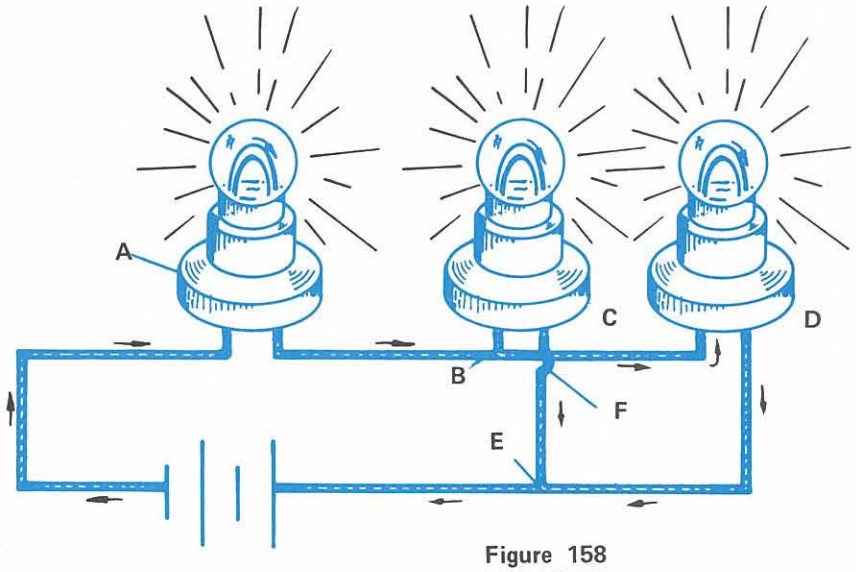


Figure 158

If the bulb in lamp C were removed, the other two would still light, since current could pass through lamp D and continue on around the circuit unbroken. If the bulb in lamp D were removed, the other two would still burn. The current flow would go through lamp C and make a complete circuit. The combination of a series-parallel circuit is used in most alarm systems. Notice the loop at F. This is the symbol used in electrical drawings when one wire crosses another.

ALTERNATING CURRENT

So far we have been working and thinking in terms of current flowing in one direction, from negative around to the various forms of resistance, and back to the positive terminal. There is another form of electricity called alternating current that behaves a little differently. The current we have already studied is known as DIRECT CURRENT. This type current is generally obtained from batteries. Alternating current is the type we have in our house. It is used in almost all domestic and commercial installations.

By its nature, direct current is not readily adaptable to raising or lowering its voltage, while alternating current is. Its voltage can easily be raised or lowered without affecting its performance. Alternating current is generally referred to as AC. Direct current is known as DC.

There is one basic difference between AC and DC current. DC current is a constant flow from negative to positive in one direction. AC current flows back and forth in the wire at regular intervals, going first in one direction and then in the other. This change of direction is known as the CYCLE. If the current is 60 cycle, it means that the current flow changes direction 60 times per second. If it is 50 cycle it changes direction 50 times per second. Sixty cycle is the type used in almost all parts of this country for AC current. Some foreign countries use 50 cycle current. To get an idea of how this change works, let's look at Figure 159. To start with, current is flowing in the direction indicated by the arrows shown at A. One sixtieth of a second later, it reverses its direction, and flows in the direction shown at B. The next sixtieth of a second it is flowing in the direction shown at A. This is the same direction it started. The next sixtieth of a second it is flowing the other way again. This goes on continuously, changing direction 60 times every second. At the exact point of reversing, which would be at point C, there would be no current; however, this happens so fast it is not noticeable. If the cycles were cut down, say to 25 cycles per second, you could see a light flicker. It would actually go out at the point where the current reverses. With this reversing action in AC current, you can see why there is no negative to positive flow of current.

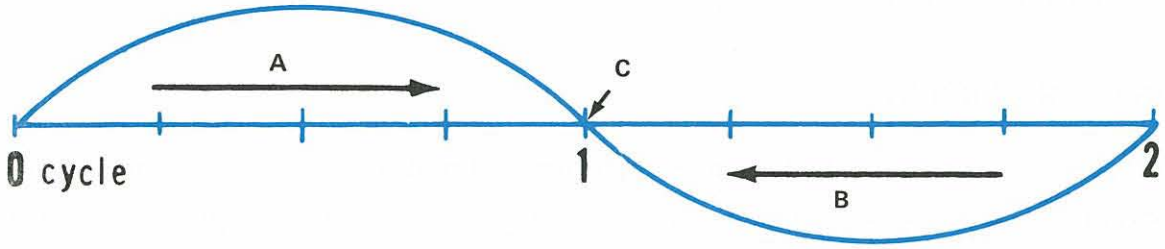


Figure 159

ELECTROMAGNETISM

Earlier we learned that if a wire were moved past a magnet, current would be produced. By the same principle, we can produce magnetism, by inducing current through a wire that is wrapped around a piece of metal. Any flow of current sets up a magnetic field and we can convert it to use.

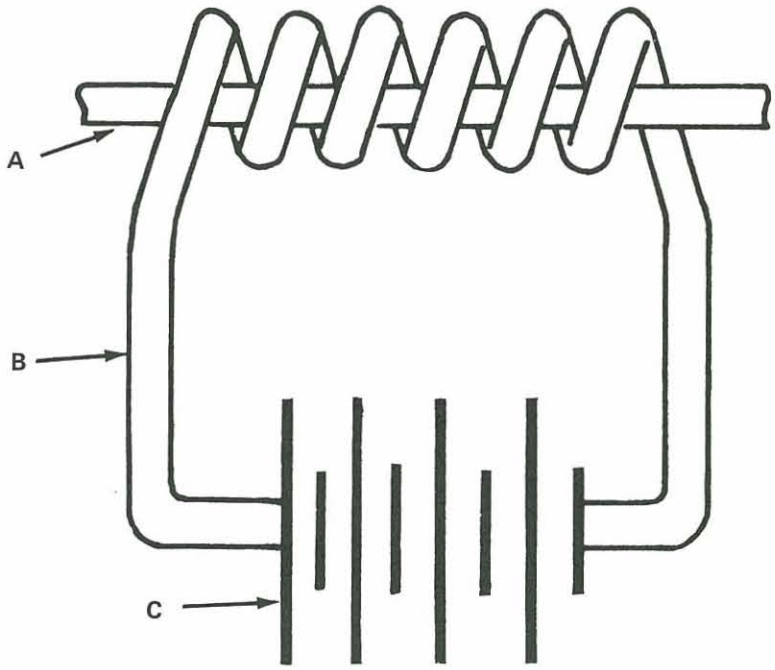
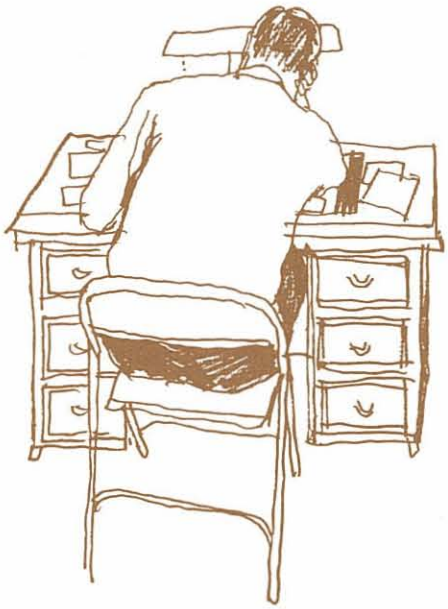


Figure 160

Figure 160 shows the simplest form of an electromagnet. A is a piece of steel rod or iron bar. Around it is wrapped a conductor, such as a piece of copper wire as shown at B. If we connect each end of the copper wire to a source of current, such as the battery shown at C, we will have a current flow through the wire. This will set up a magnetic field. The current will magnetize the bar, and make an electromagnet out of the bar. When current is stopped the magnetism will no longer be in the bar. There are many electrical components that have this principle.

To increase the magnetic force you can increase the number of turns of the wire or increase the current. This will make the magnet stronger. We'll go more into the electrical functions as they relate to small engines when we get into the magneto and ignition sections. At this point we just want to be familiar with some of the basic functions before we go into electrical starters.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 17
ELECTRICITY

FOLEY-BELSAW INSTITUTE OF
SMALL ENGINE REPAIR
6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The basic types of electrical circuits are _____. _____
   a. positive, negative
   b. closed, open, series, parallel
   c. volts, watts, ohm
   d. none of the above

2. Electric current will flow through _____. _____
   a. liquids
   b. solids
   c. gasses
   d all of the above

3. _____ is the unit of measure to designate the amount of current that flows through a conductor in a given amount of time. _____
   a. ampere
   b. conductor
   c. resistance

4. A cell produces _____ volts. _____
   a. .5
   b. 1.0
   c. 1.5

5. Electricity will produce magnetism and magnetism will produce electricity. _____
   TRUE
   FALSE

6. _____ is a unit of measure to designate the force of current. _____
   a. volts
   b. cells
   c. magnetism

7. A conductor is a material through which electric current will flow. _____
   TRUE
   FALSE

8. Electricity may be defined as a form of energy. _____
   TRUE
   FALSE

(Continued on page 2)

9. Opposition to the flow of current is called _____. _____
   a. resistance
   b. volts
   c. ampere

10. When two or more _____ are combined they are known as a battery. _____
    a. closed circuit
    b. open circuit
    c. cells

11. Two methods of producing electricity are by mechanical action or chemical action. _____
    TRUE
    FALSE

12. Insulators have a _____ to the flow of current. _____
    a. high resistance
    b. low resistance
    c. no resistance

13. The unit of measurement for measuring resistance is called the _____. _____
    a. energy
    b. volts
    c. ampere
    d. ohm

14. When wires are moved past a magnet, or a magnet is moved past wires, electricity is produced. _____
    TRUE
    FALSE

15. Magnetism can be produced by inducing current through a wire wrapped around a piece of metal. _____
    TRUE
    FALSE

16. A short introduced into an electrical circuit will cause heat. _____
    TRUE
    FALSE

17. Direct current is readily adaptable to raising or lowering its voltage. _____
    TRUE
    FALSE

18. When we connect cells in parallel, the voltage is not increased. _____
    TRUE
    FALSE

19. Current will follow the path of the most resistance. _____
    TRUE
    FALSE

20. The change in direction of alternating current is known as a _____. _____
    a. cycle
    b. close circuit
    c. parallel circuit

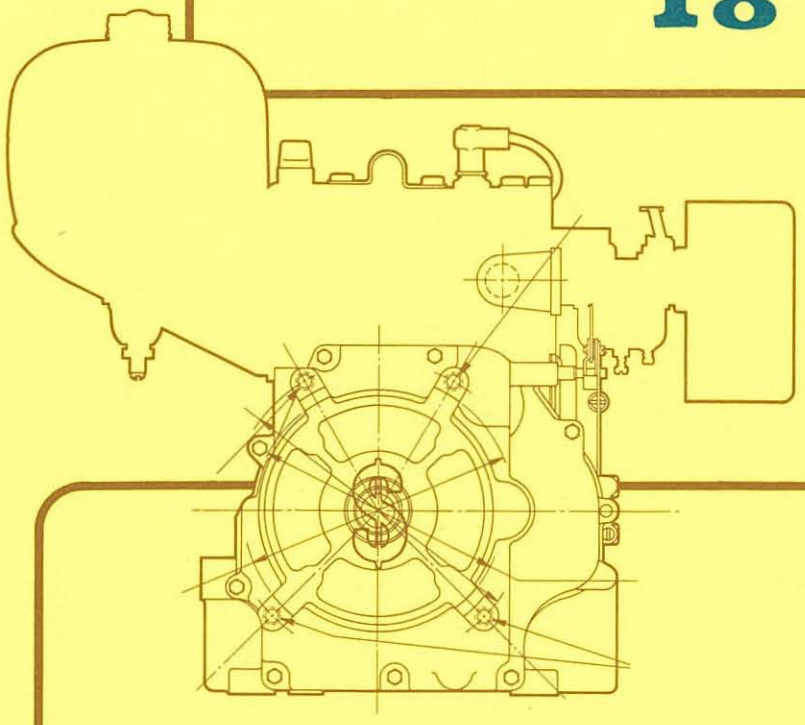
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

18



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...and let's find out all about -- **ELECTRIC STARTERS**

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ALTERNATING CURRENT ELECTRIC STARTERS

Starting motors and generators are quite similar in construction. When an electric current is applied to a starter the armature will rotate. When the armature of a generator is rotated it will produce electricity. When a starter motor is turned by an external force it has the qualifications to generate electricity. Since starters and generators are so similar in construction and operating principles they are often combined into one unit. Electric starters are becoming more popular on small engines, especially on engines with 5 or more horsepower. Some starters are designed to operate on alternating current such as you have in your house. Others are designed to operate on direct current like the battery in your car.

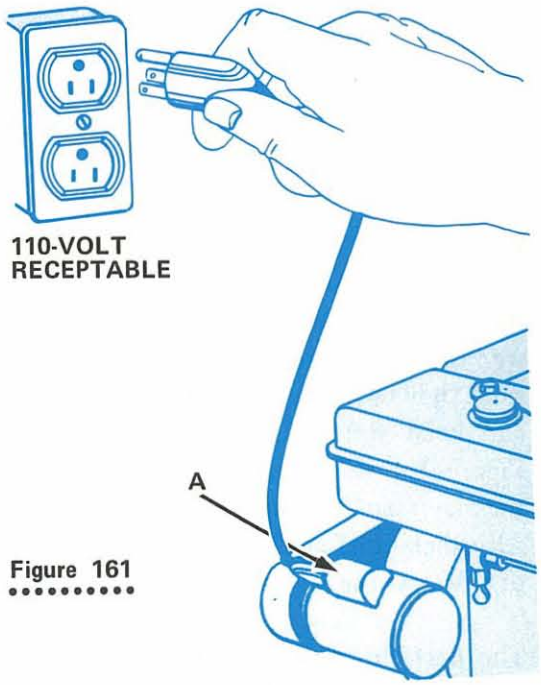


Figure 161

An alternating current starter is shown in Figure 161. This is nothing more than an electric motor that operates on regular house current. On the motor shaft there is a pulley, pinion or clutch that engages with the flywheel for starting. We'll cover each of these drive mechanisms later. When the starting motor, shown at A, is connected to current it begins turning. The drive engages the flywheel and turns the engine.

DIRECT CURRENT STARTERS

Direct current starters are operated from a battery. They have the same basic principle as the alternating current starter except they are designed to operate from either a 6 or 12 volt battery supplying direct current.

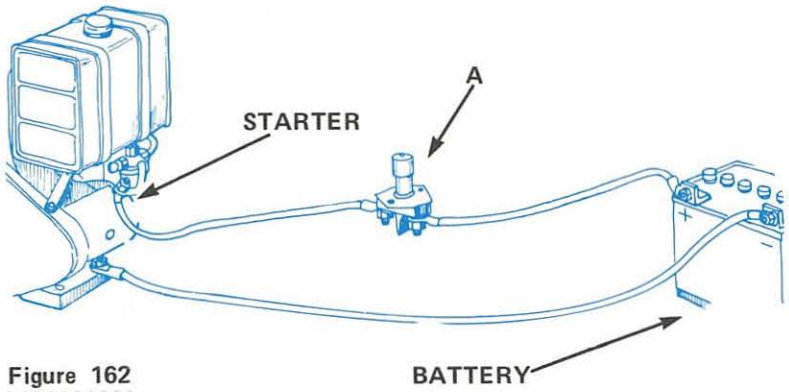


Figure 162

Figure 162 shows a typical direct current starter. When the switch, shown at A, is depressed it completes an electrical circuit through the starter so it begins turning. As soon as the engine starts the starter button is released and no current from the battery will reach the starter motor.

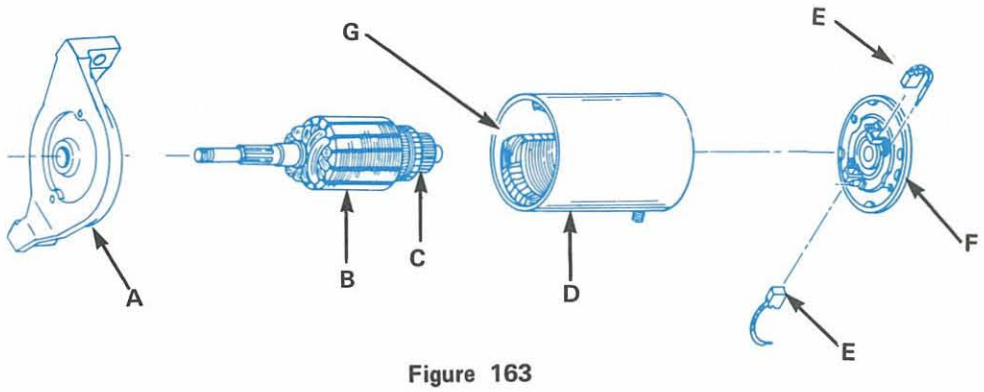


Figure 163

ELECTRIC STARTER BASIC COMPONENTS

When talking about electric starters, remember we are also covering electric generating units since they both have the same major components and need almost the same service procedures. Figure 163 shows an exploded view drawing of the major parts of an electric starter or generator. All other bolts and hardware have been left out of this drawing.

The part shown at B is the armature. It turns inside the housing D and is carried by end plates A and F. There are bearings in these end plates and the armature turns in these bearings. The part shown at C is the commutator. This is actually part of the armature but it is known as the commutator at this particular point.

Inside the housing is the field coil, which is shown at G. The two brushes that operate against the commutator are shown at E. As we mentioned before, the only basic difference between a starter and a generator is one receives current and the other produces current. Operating current is applied to the brushes of a starter to make it operate. A generator is operated from an outside source of power and gives out current through the brushes.

STARTER FUNDAMENTALS

An electric starter motor used for starting an internal combustion engine operates on the principle that a current carrying conductor has a tendency to move from a strong magnetic field to a weak magnetic field.

An electric starter is actually a special type of electric motor designed to produce a great amount of power for its size. In order to have a motor that could operate continuously that would produce this great amount of power, it would be necessary to have a motor 5 or 6 times the size of a regular starting motor. As we mentioned before, for every mechanical advantage there is a disadvantage. The disadvantage in the case of the starter motor is that it can only be operated continuously for a very short time.

In order to produce high power output it is necessary to have a high current, and a high current creates heat. If a starter motor is operated for any prolonged length of time it will overheat and burn up. Generally about 30 to 45 seconds should be the limit for continuous operation without allowing the starter to rest for a few minutes.

It will not be necessary to go into the complete theory of operation to learn starter and generator servicing. This would be a complete electrical course in itself. There are just a few general service procedures that we can follow for checking and servicing these units.

SERVICING STARTERS AND GENERATORS

Because of the similarities in the basic construction of both units the service procedures are almost the same. There are six general areas we should pay particular attention to when checking starters and generators. In these six general areas of possible trouble, two are in the armature, two in the field and two are general to both the armature and the field.

The first part in servicing these units and most any other engine components is to clean it so the parts can be inspected and handled. It is best to first blow them off with air if it is available and then wipe clean with a rag soaked in solvent.

BEARING CHECK

Before disassembling check first for worn bearings. The bearings are located at each end of the armature shaft. Check them for excessive end or side play. If the starter can be tested before removing from the engine this bearing trouble will often be noticeable by the sound when the starter is operated. Another check and sure sign of worn bearings is the armature. If the bearings are worn they will allow the armature to drag on the field windings or core. If bearings show the slightest amount of wear they should be replaced since continuous operation will make them cause more serious trouble. Always replace both front and rear bearings as a pair.

BRUSH CHECK

Brushes are one of the most common causes of starter problems since they are made of soft material and receive a lot of wear. They are designed this way and are considered an expendable or replaceable part of the starter. To check the brushes and commutator, first remove the cover band used on most starters.

Figure 164 shows the commutator and brushes on a typical starter. To inspect these parts it is necessary to first remove the cover band shown at A. Check the condition of the commutator in the area shown at B and the brushes shown at C. Also, check the condition of the brush holder shown at D for alignment or damage. Some units do not have a cover band and it is necessary to remove the bolts through the frame that holds the two end plates together.

ELECTRIC STARTER

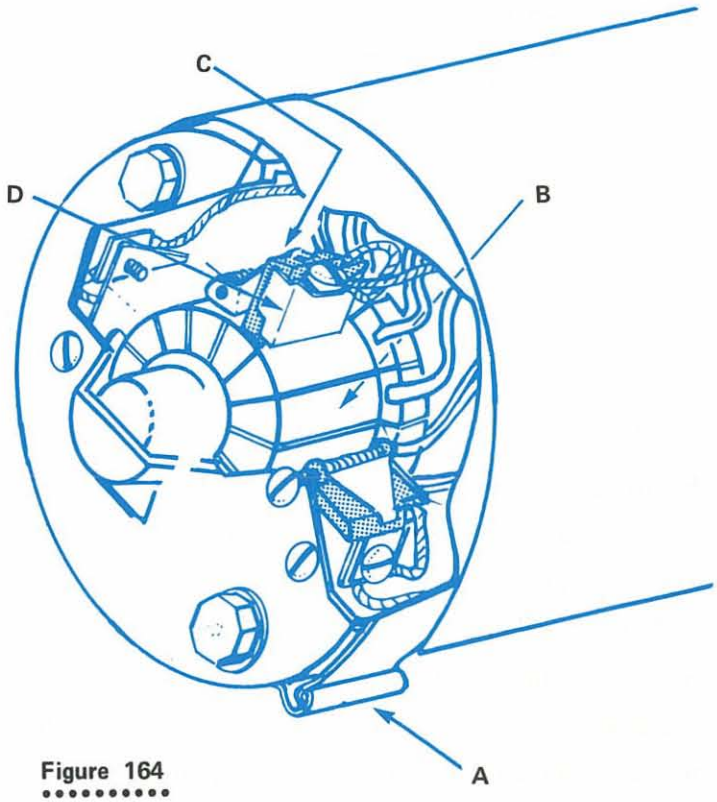


Figure 164

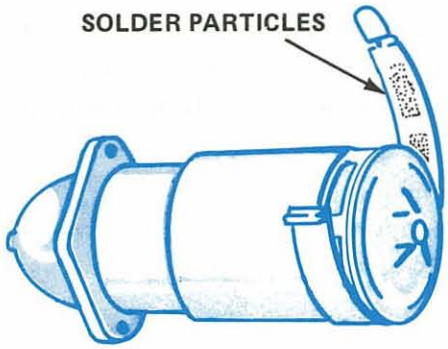


Figure 165

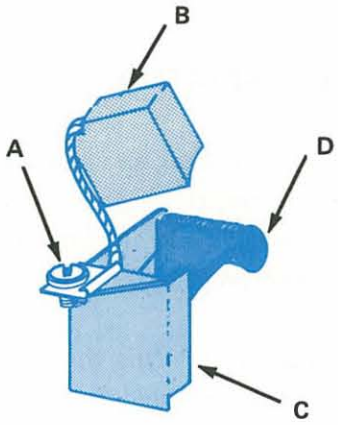


Figure 166

If a starter has been overheated it will melt the solder used in the construction of the armature and part of the solder will be thrown against the cover band or inside of the housing. Figure 165 shows the cover band of a starter or generator that has become overheated. There are four primary parts to most brush assemblies. First there are the wire leads coming from the field. If you are working on a generator, there may be either two or three brushes. A starter generator combination will generally have two brushes.

Figure 166 shows a typical brush assembly. The wire lead coming from the field is shown at A. This wire lead is connected direct to the brush as shown at B. This brush is made of soft carbon material. The brush holder is shown at C. After the brush is inserted in the holder it is held in place by a spring clip shown at D. This spring clip holds a slight amount of tension on the brush and forces it against the commutator under light pressure.

Figure 167 shows the complete brush assembly in relationship to the commutator. The wire lead coming from the fields is shown at A. The brush tension spring shown at B is pressing down on the brush shown at C. The brush holder D is attached to the tension clip with a small spring. Notice the brush rides on the commutator at E. The critical part of brush wear is shown at F. If this brush is allowed to continue to wear, the brush holder will gradually come in contact with the commutator.

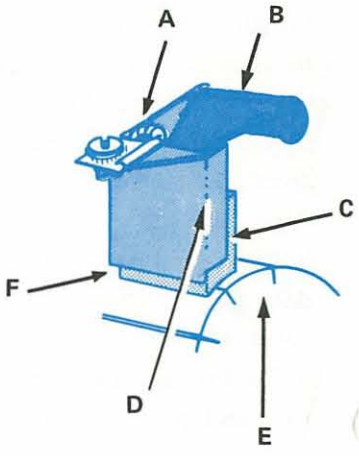


Figure 167

Figure 168 shows what will happen if the brush is allowed to wear too far. The brush tension spring can only push the brush so far and it will hit the holder. The brush will continue to wear until the holder starts to contact the commutator as shown at A. When this begins to happen it will damage the commutator in a very short time.

Brushes should never be worn more than half their original length. If there is indication that the brushes are worn as much as 25% of their original length it would be a good idea to replace them.

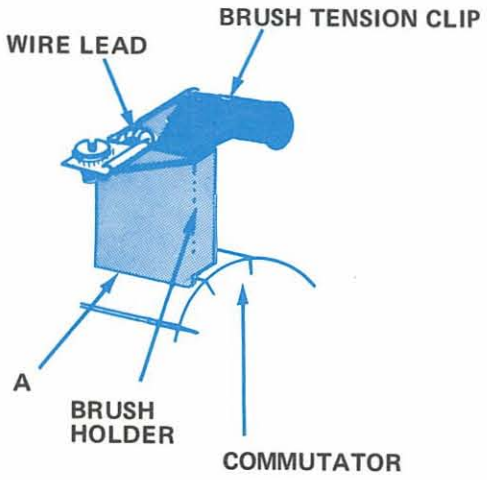


Figure 168

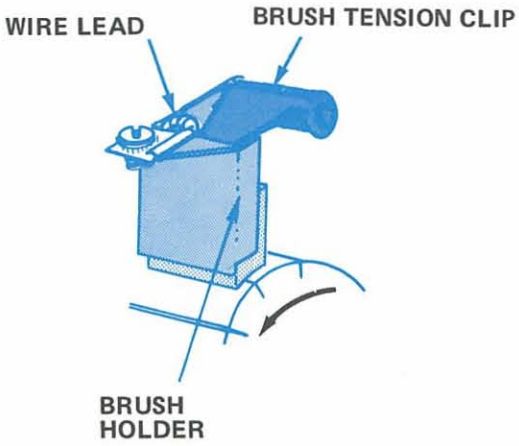


Figure 169

Figure 169 shows the method of installing new brushes. First remove the wire lead of the old brush, turn back the brush tension clip and remove the old brush. To install the new brush, first attach the wire lead, then insert it in the brush holder as shown. Be sure the beveled edge of the brush is toward the direction of rotation of the commutator as shown by the arrow. If the brushes are installed with the beveled edges going against the direction of rotation, the low segments of the commutator would have a tendency to chip off the beveled edges of the brushes. When installing new brushes, check for binding of movement in the holders. If a brush wants to bind in the holder, remove it and wipe clean with a cloth.

COMMUTATOR CHECK

Brushes are one of the primary causes of trouble, however, the commutator will often run a close second in developing problems. It should be inspected for wear and roughness. If the commutator is rough or out of round, it will have to be machined in a lathe and this should be done by a shop having proper facilities. Often the commutator will only have a glaze and dirt on the surface. If this is present it can be cleaned while the starter motor or generator is running. Either a brush seating stone or sandpaper can be used to clean glaze from the commutator, as shown in Figure 170.

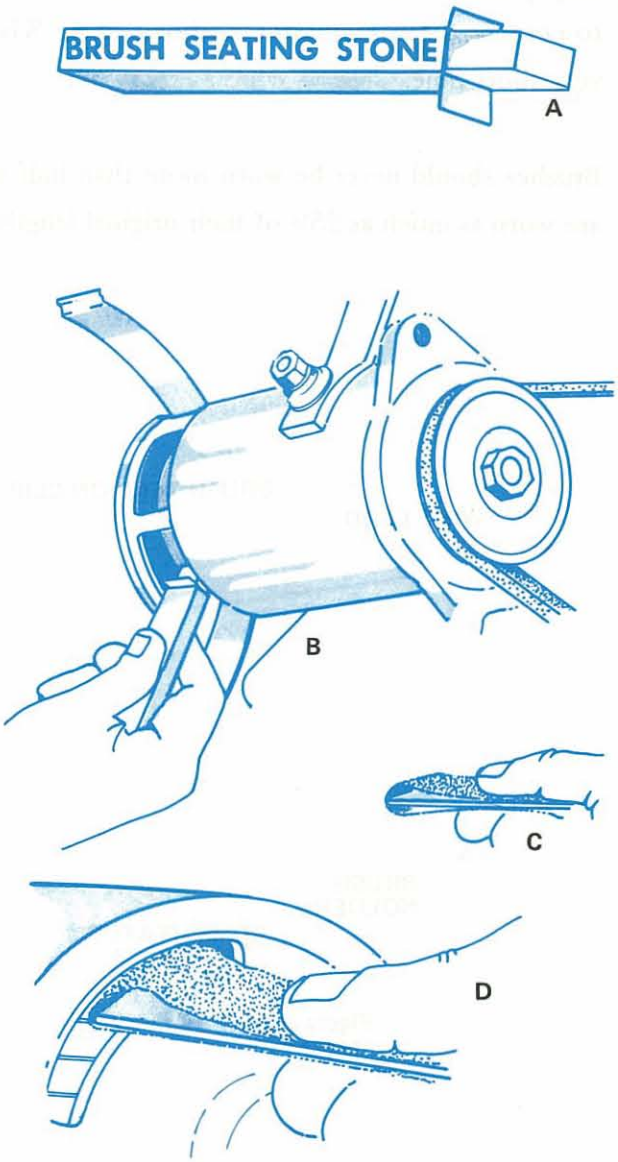


Figure 170

Some repairmen prefer to use the brush seating hone shown at A while others use No. 00 sandpaper on a piece of thin wood with a square end as shown at B. This should be sandpaper, not emery cloth, because emery cloth contains fine particles of metal that act as the abrasive. This can cause arcing and burning which will cause rapid wear.

Clean the commutator while the starter is turning the engine.

CAUTION

Be sure to disconnect the spark plug first. With the starter turning, move the sandpaper back and forth on the commutator until all gum and glaze has been removed. If the starter has a cover band, you can work through this area as shown at C. Sometimes it is necessary to work through an opening in the end plate as shown at D.

SEATING NEW BRUSHES

In cleaning the commutator there probably was enough abrasive action on the brushes that they became seated with the commutator. The brushes should make a very close fit with the commutator surface. If not, it may be necessary to seat them by using a piece of sandpaper as shown in Figure 171. Place the sandpaper with the abrasive side against the brush. Pull the sandpaper in the direction shown by the arrow at A so it will move against the beveled edge of the brush.

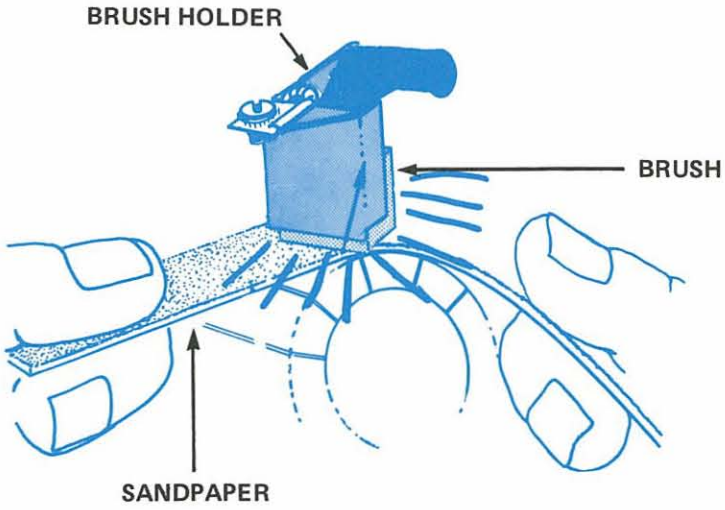
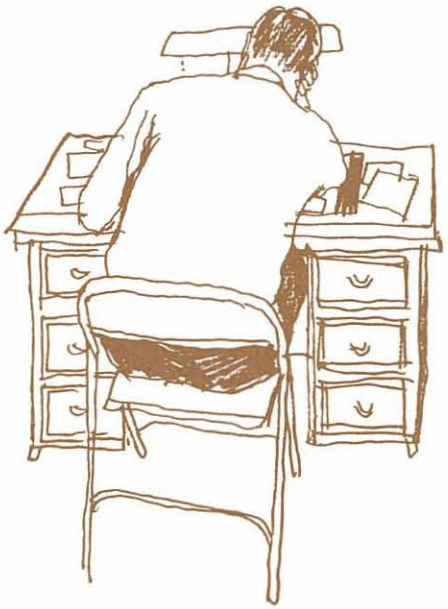


Figure 171

GENERATORS

The basic service procedures for generators would be very much the same as for starting motors. Other than basic service, as on starters, most small shops send generating and starting units to specialty shops for repair since there is a considerable amount of electrical test equipment necessary for complete rework of these units.

The procedures we have covered will correct starter and generator problems in most cases, however, without quite an electrical background and test equipment it would be best to send this work out to shops specializing in this type work.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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EXAMINATION ON LESSON 18
ELECTRIC STARTERS

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NAME ___ _____ Student No. _____
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ADDRESS ___ _____ Date_ _____

CITY-STATE-ZIP _ _____ _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. It is not advisable to replace both bearings on a starter or generator if only one is bad. _____
   TRUE
   FALSE

2. Direct current starters are operated from _____. _____
   a. battery
   b. commutator
   c. armature

3. The brushes on a starter or generator ride against the _____. _____
   a. endplate
   b. commutator
   c. battery

4. When an electric current is applied to a starter the armature will rotate. _____
   TRUE
   FALSE

5. Generator and starter bearings should be checked for excess endplay as well as sideplay. _____
   TRUE
   FALSE

6. Starters and generators can be combined into one unit. _____
   TRUE
   FALSE

7. A starter motor may be operated continuously the same as a generator. _____
   TRUE
   FALSE

8. Generators and starter brushes are made of a _____ material. _____
   a. carbon
   b. emery
   c. hard

9. A high current will create heat. _____
   TRUE
   FALSE

(Continued on page 2)

10. Sand paper, not emery cloth, may be used to clean the commutator. _____
    TRUE
    FALSE

11. When the _____ is rotated, it will produce electricity. _____
    a. endplate
    b. brushes
    c. armature

12. Brushes should never be worn more than _____ the original length. _____
    a. 1/4
    b. 1/2
    c. 3/4

13. Label the reference letter of the part listed below as they apply to the electric starter or generator shown in Fig. 18-1.
    brushes _____
    field coil _____
    housing _____
    armature _____
    commutator _____
    endplate _____
    endplate _____

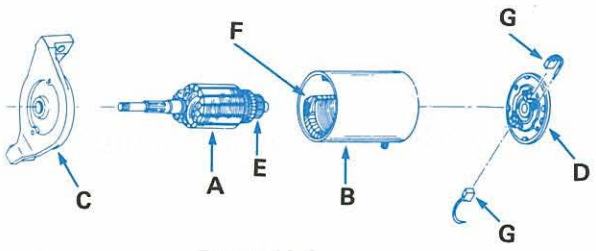


Figure 18-1

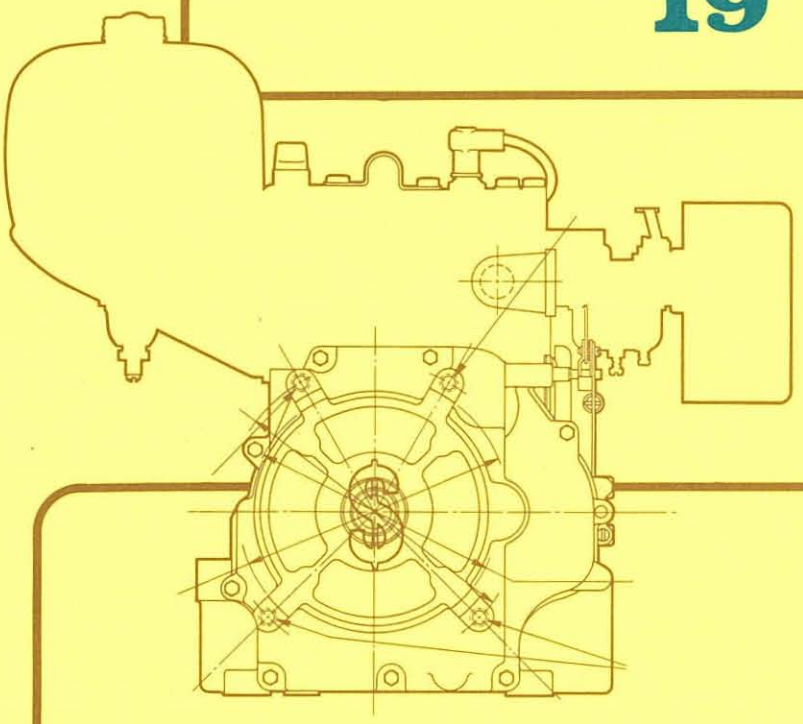
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

19



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...and let's find out all about --

ELECTRIC STARTER DRIVES

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ELECTRIC STARTER DRIVES

The purpose of the starter drive mechanism is to engage the starter with the flywheel for cranking the engine and disengaging the starter from the flywheel once the engine is started. It is very important that the starter gear be disengaged immediately from the flywheel once the engine is started.

Generally the gear ratio from the starter motor to the flywheel is 15 or 20 to 1. This requires the starting motor to operate at a rather high speed which gives it more power when cranking the engine. If the starter is not immediately disengaged as soon as the engine is started it will become the driven gear since the engine will begin turning the starter. This could speed the armature up to 20,000 RPM or more if it is not disengaged immediately. The various types of starter drives are designed to perform this function. There are basically three types of drive mechanisms used on most small engines. These can be either 110 volt A.C. starting motors or low voltage D.C. starting motors operated from a battery. A very popular and common starter drive unit used on many small engines and automotive equipment is the bendix-type starter drive.

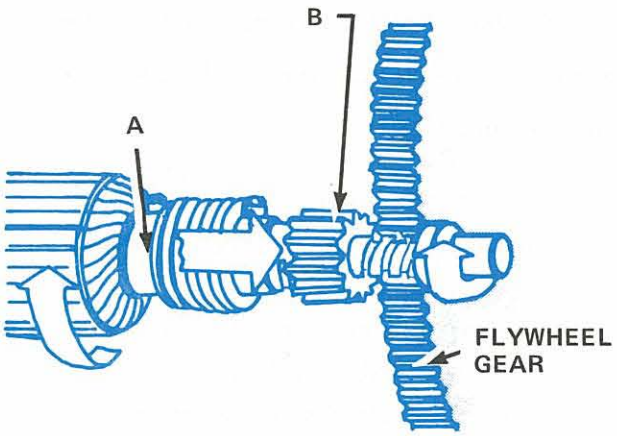


Figure 172

BENDIX DRIVE

Figure 172 shows a typical bendix drive design. When the starter switch is turned on the starter motor shaft, shown at A, begins to turn. The pinion gear, shown at B, does not turn because in its present position it is riding free on a sleeve on the shaft. The pinion gear does not immediately begin to turn because of inertia. This is the resistance a stationary body has to changing motion.

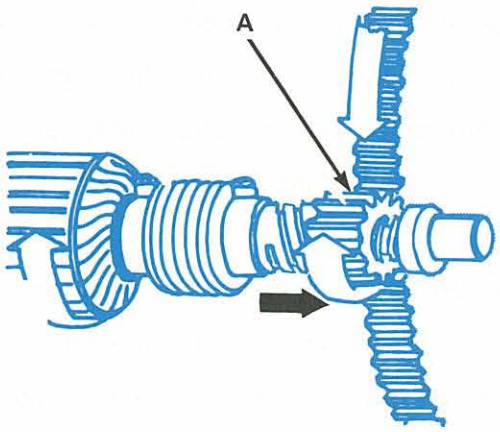


Figure 173

The pinion gear begins to move lengthwise on the shaft toward the flywheel as shown in Figure 173. It moves until it engages the flywheel as shown at A. The pinion gear then begins to turn the flywheel gear which is attached to the flywheel and then begins cranking the engine.

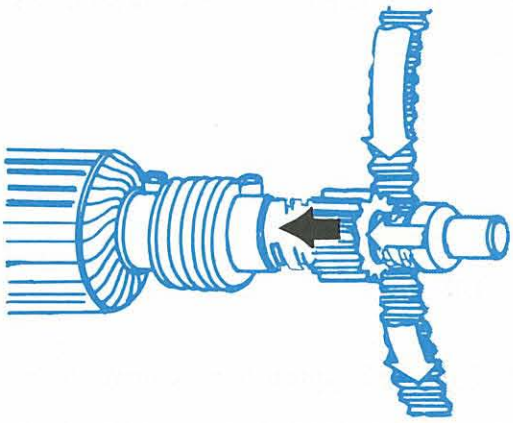


Figure 174

When the engine starts the starter switch is turned off. The pinion gear is driven by the turning flywheel and turning much faster than the starter shaft. It then swings back on the threaded shaft away from the flywheel gear, as shown in Figure 174.

TROUBLE SHOOTING BENDIX DRIVE

A. Worn spring lock dogs.
B. Broken or damaged bendix spring.
C. Worn gear shaft and sleeve.
D. Chipped or damaged pinion teeth.
E. Worn or damaged drift spring.

Figure 175 shows the trouble areas for this type drive. These are the parts most likely to cause trouble and should be inspected carefully every time the starting unit is serviced.

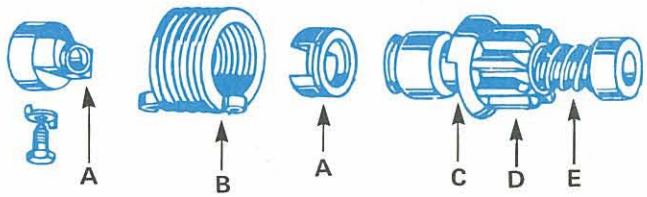


Figure 175

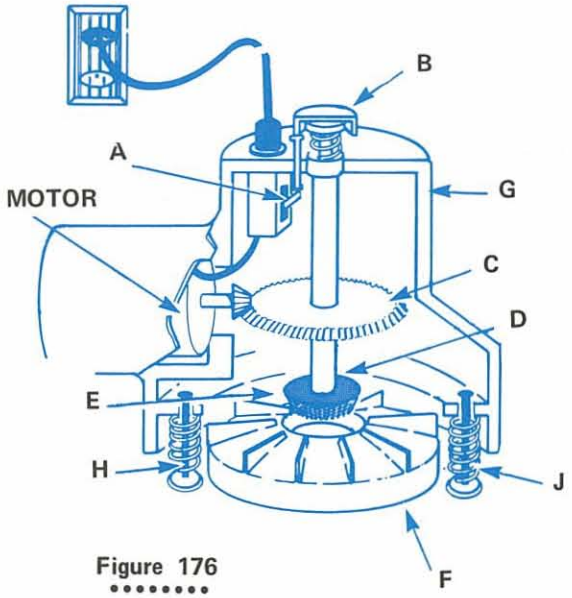


Figure 176

CONE FRICTION CLUTCH DRIVE

There are many variations in the design of friction clutch starters but most of them have similar operating principles. Figure 176 shows the basic operating principles of this type starter drive mechanism. These are generally used on alternating current starters using motors operating on regular house current.

The motor switch, shown at A, is in the off position. When the switch control button, shown at B, is pushed down the motor begins turning and drives the larger gear shown at C. This gear turns the starter shaft D. The cone shaped drive clutch shown at E is attached to the starter shaft and also turns. This drive clutch is not engaged with the flywheel F at this time. The motor is turning the larger gear, starter shaft and the cone clutch drive. All of this mechanism is connected directly to the starter housing shown at G. This entire unit is supported on guide post as shown at H and held above the flywheel by release springs shown at J.

Figure 177 shows the starter turning the flywheel. The starting motor began turning the large gear, shown at A, before the cone drive clutch, shown at B, was engaged with the flywheel C. When the entire housing is pushed down, the cone drive clutch engages the flywheel and begins turning the engine. As soon as the engine starts the downward pressure on the housing is released and the clutch becomes disengaged from the flywheel as shown in Figure 176. The switch releases as soon as the housing is brought back to the original position.

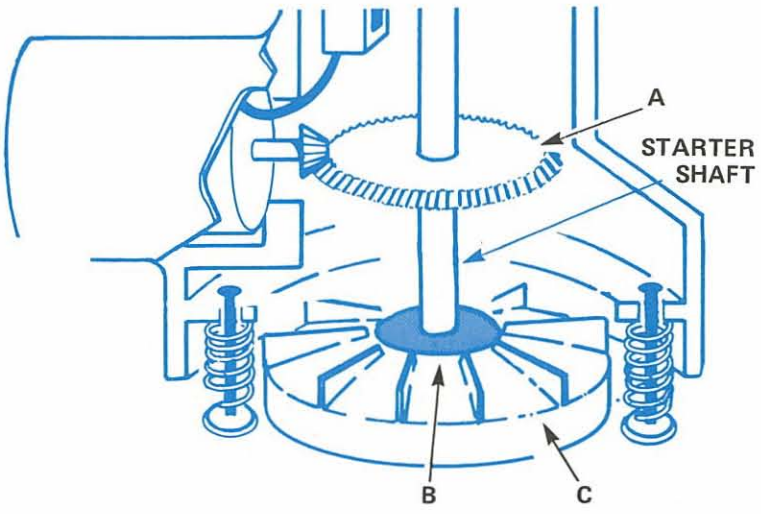


Figure 177

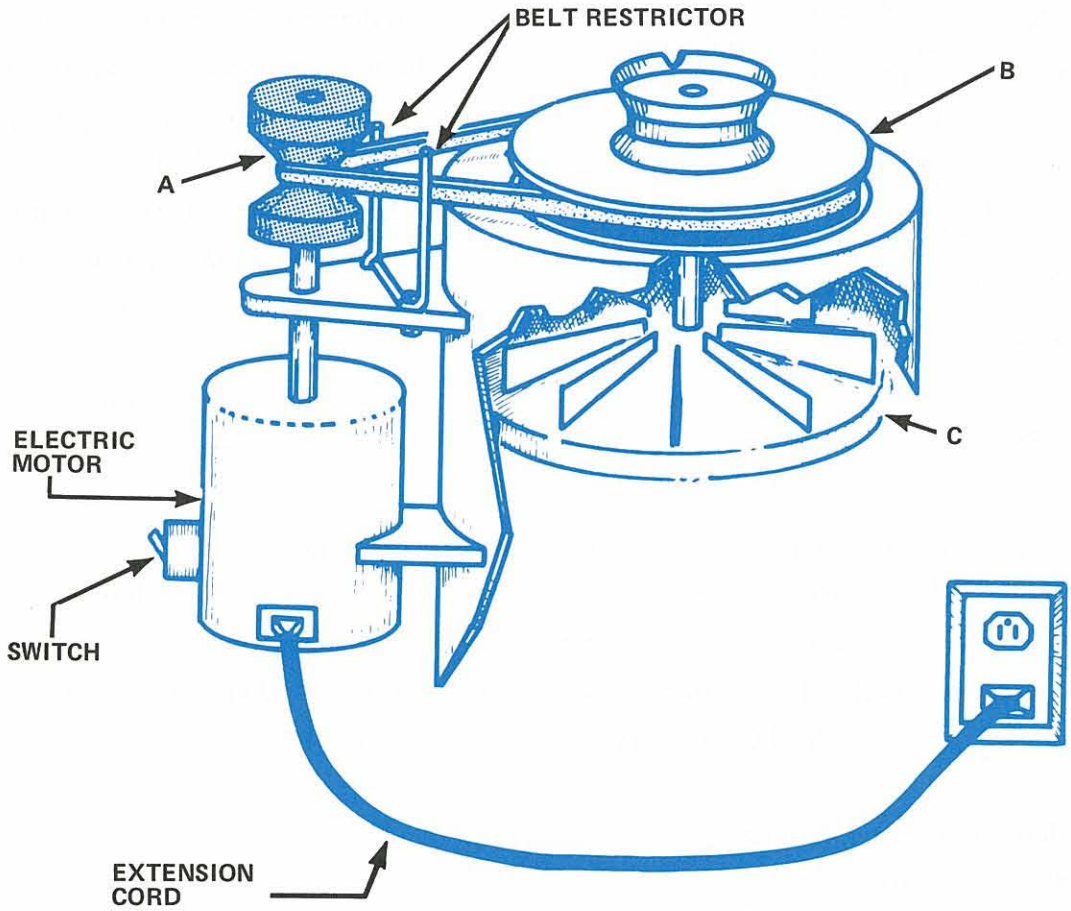


Figure 178

SPLIT PULLEY CLUTCH DRIVE

Another electric starter uses a split pulley design for engaging and disengaging the starting mechanism. Figure 178 shows the basic design of this type drive. The split pulley clutch, shown at A, is connected by a belt drive to the drive pulley shown at B. This pulley is connected at all times to the flywheel shown at C. Any time the flywheel is turning the pulley B is turning. To keep the flywheel from turning the electric motor after the engine is started, the split pulley will release the belt tension and allow the belt to ride free on the pulley.

Figure 179 shows the design of this split pulley. The pulley halves are separated, as shown at A, when the electric starting motor is not running. The belt is not engaged with the pulley and is not turning. When the motor starts the two halves of the pulley come together, as shown at B. This engages the drive belt which turns the pulley connected to the flywheel. When you turn on the switch the electric motor starts. The top half of the pulley, shown at C, is attached to the motor shaft with a set screw and turns with the motor shaft. The lower half of the pulley, shown at D, is not keyed or attached to the motor shaft. This allows the shaft to turn in this side of the pulley.

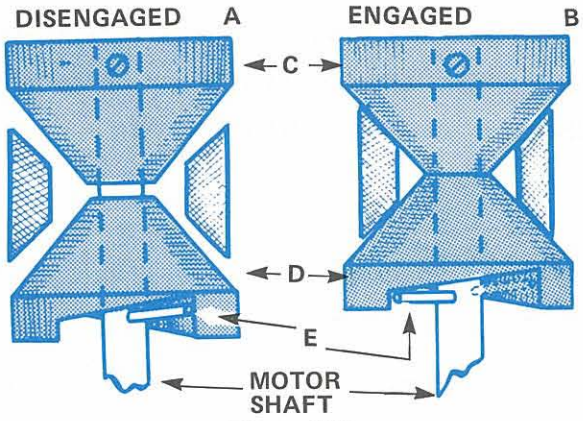


Figure 179

The lower half of the pulley does not turn momentarily because of inertia, which is the resistance of a stationary body to a change of direction or motion. As a result, a pin in the starter shaft, shown at E, pushes against the incline on the pulley and forces the lower pulley half up to meet the top pulley half. When this happens the space between the two pulley halves is closed and engages the belt as shown. This creates belt tension and the necessary friction to drive the larger pulley on the crankshaft. When the engine starts and the starter switch is turned off, the electric motor stops. With the engine running, belt tension applied to the split pulley forces the moveable lower half back down to the original position shown at A.

The belt rides free on the split pulley while the engine is running. To keep the belt from running off the split pulley when running in this loose position, a belt restrictor as shown in Figure 179A, is used to keep the belt in place.

There are many variations of starter drives, however, most of them will be similar to one or more of the basic designs we have covered. All of them use some form of clutch, pinions, gears or belts to engage and disengage the starter driving mechanism.

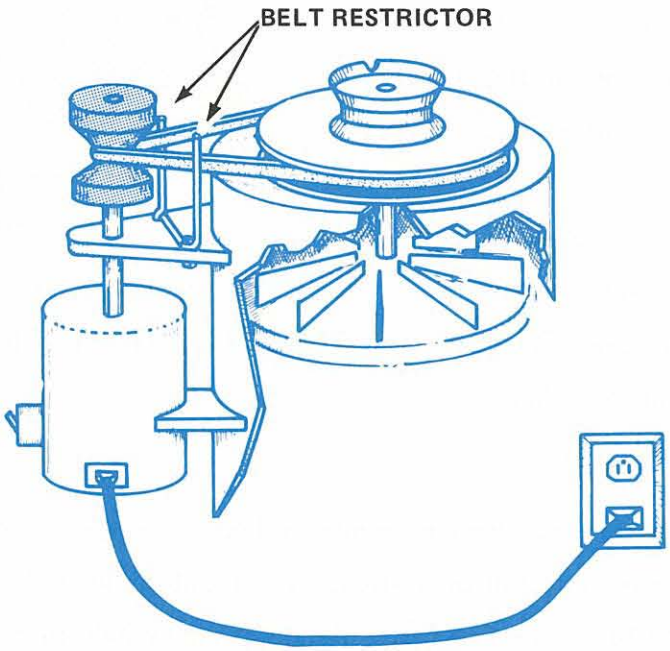
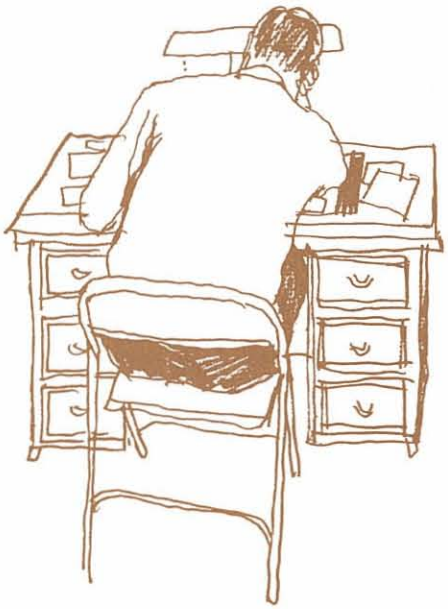


Figure 179A

In working with any equipment using a high voltage starting motor the extension cord used to operate the starting motor should always be plugged into the starting motor first and then into the voltage supply. It is possible to get a spark when connecting electrical current. If the spark were to occur on the starting motor end of the current supply it could cause a fire since, in most cases, it is near the fuel supply. It is also very necessary to use a three-wire grounded extension cord.

In some electrical instructions you will find reference to 110 volt and others 120 volt alternating current. These are the minimum and maximum allowable variations that can occur due to the supply of current requirements at the particular time or area. When electrical current use is highest, as in the hot summer when air-conditioning is in use, the voltage is likely to be down compared to more clement weather when they are not in such general use.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 19
ELECTRIC STARTER DRIVES

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NAME _____ Student No. _____
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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. In working with any high voltage starting motor, the extension cord should always be plugged into the motor first. _____
   TRUE
   FALSE

2. The basic types of drive mechanisms used on most small engines are _____. _____
   a. bendix
   b. cone friction clutch
   c. split pulley
   d. all of the above

3. The purpose of the electric start drive mechanism is to engage the starter with the flywheel. _____
   TRUE
   FALSE

4. Generally, the cone friction clutch drive starters use motors that operate on regular household alternating current. _____
   TRUE
   FALSE

5. Label the reference numbers for the parts listed below as they apply to the bendix drive shown in Fig. 19-1.
   gear shaft and sleeve _____
   drift spring _____
   bendix spring _____
   lock dog _____
   pinion gear _____

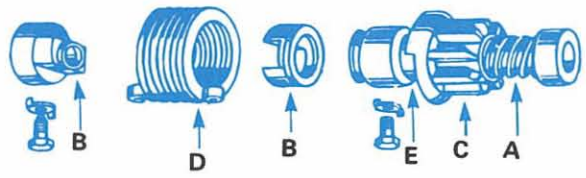

Figure 19-1

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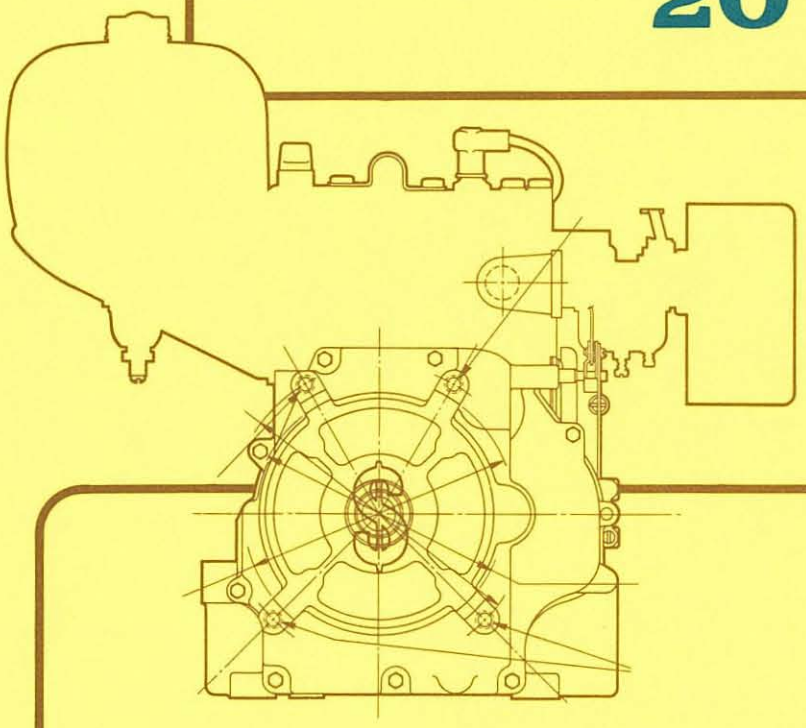

TURN THIS PAGE

...and let's find out all about --

BATTERY AND STARTER CIRCUITS

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BASIC STARTING CIRCUIT WIRING

The basic starting circuit of a small engine consists of the battery, starter motor and starting circuits. The battery, shown at A, supplies the starting current. This is usually 6 or 12 volts. The ground wire, shown at B, is the negative terminal of the battery and is grounded to the frame of the installation. The positive terminal of the battery shown at C, goes through the starter switch at D and then to the starter. When the starter switch is closed, an electrical circuit is completed between the battery and the starter. Current supplied by the battery flows from negative to positive. This starting mechanism, although it is adequate for many applications, generally requires more than the components shown in Figure 180.

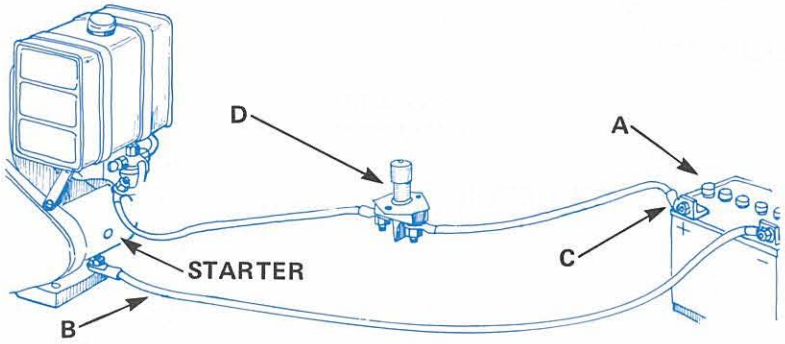


Figure 180

STARTER-GENERATOR CIRCUIT WIRING

In the section on servicing starters and generators we have already covered their similarities. A starter will operate as a motor when it is supplied with an outside source of electrical current. A generator, when supplied with an outside source of power, will produce electricity. With a few modifications in their design engineers have been able to combine these two units into one basic starter-generator unit. Because of their lighter weight and compactness, this design is used on most small engine applications requiring the use of a generator.

Starter-generator units are generally used on engines installed on larger equipment using 5 or more horsepower. This generally covers the field of riding equipment such as lawnmowers and garden tractors. Most of these units also need lighting and other types of electrical equipments.

The function of the starter is to supply energy to turn the crankshaft for starting the engine. The function of the generator is to charge the battery to replace the energy drained from it by using the starter motor and current used for operating lights and other electrical equipment. If the generator did not replenish the energy, the battery would soon go dead.

Batteries can be overcharged and severely damaged. To prevent this a regulator is introduced into the electrical circuit that prevents the battery from receiving an excess amount of charge. The regulator also prevents the generator from overwork and excessive output. Without some means of control the generator would be overworked and the battery receiving an excess of charge would become hot. This would cause the water in the battery to heat and evaporate.

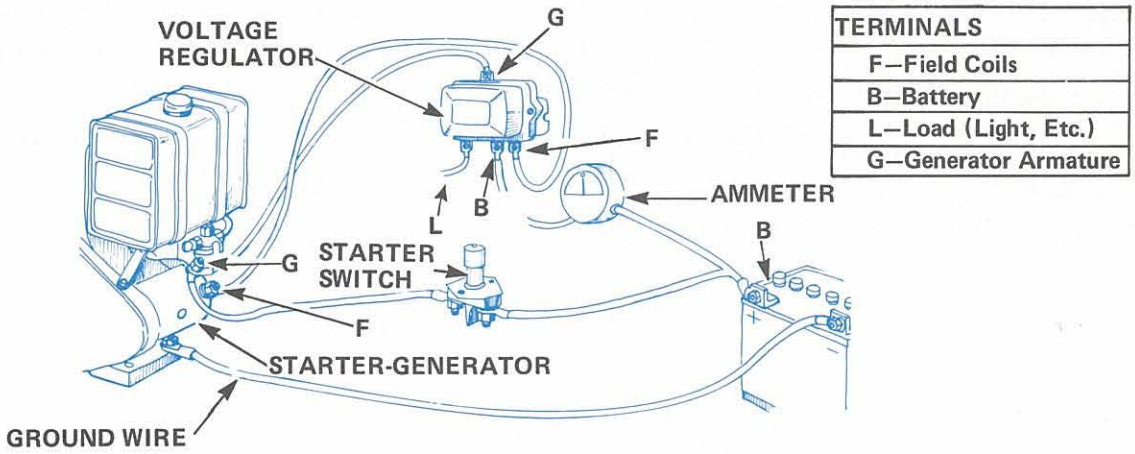


Figure 181

STARTER-GENERATOR WITH REGULATOR

Figure 181 shows the same basic circuit wiring as Figure 180 except a voltage regulator and ammeter have been added to the system. The ammeter is used to tell the operator what the generator is doing. If it is charging very little or none, the reading will be very low. Sometimes the ammeter is replaced by a red light that is off when the generator is supplying charge to the battery. When the red light is on the generator is not supplying charge to the battery.

Notice the wiring circuit when the regulator has been added to the system. Almost all regulators used on small engines will have the four terminals shown at L, B, F and G. They will generally be marked with these letters. The positive battery terminal shown at B goes to the regulator terminal marked B or Batt. This circuit goes through the ammeter.

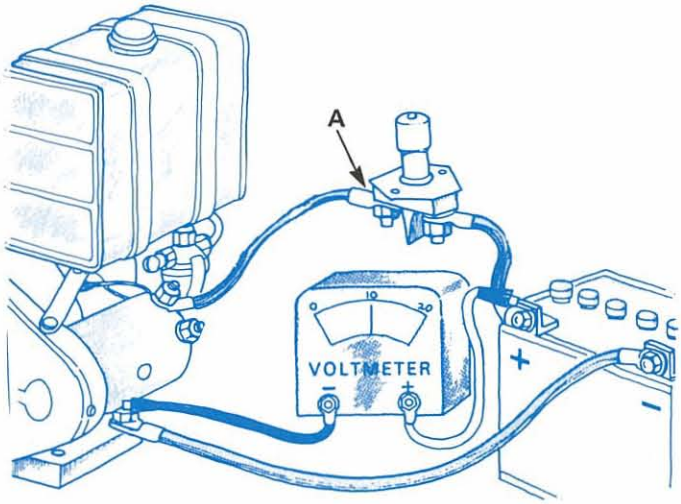
The terminal F goes from the regulator to the field coil terminal of the starter generator. The terminal G goes from the regulator to the generator armature terminal of the starter generator. There is one more terminal shown at L that appears to go no where. This supplies current for the load, which would be the lights and any other accessories requiring electrical current. When terminal L is connected to a load, such as light, and the other terminal of the load is connected to ground, current is supplied to operate accessories. The key start switch also connectes to this point.

TROUBLE SHOOTING D.C. STARTER CIRCUITS

The sequence of checking is very important in locating trouble in the starting circuit. First the battery has to be checked to be sure it is satisfactory. We'll cover the complete servicing and checking of batteries just a little later in the course. If a voltmeter is used to check the battery it must be connected negative to negative and positive to positive. The negative lead of the voltmeter must be attached to the negative terminal of the battery.

If the battery is not good it will be necessary to use a good battery to follow the complete system checking, since every step in this checking operation depends on the previous checks. Anything that does not check out should be repaired before continuing.

Figure 182 shows the first step in checking the starting system. Any voltmeter capable of registering between 1 and 12 volts D.C. is adequate for checking the battery voltage. Connect the positive terminal of the voltmeter to the positive terminal of the battery as shown and the negative terminal to the ground terminal of the starter-generator.



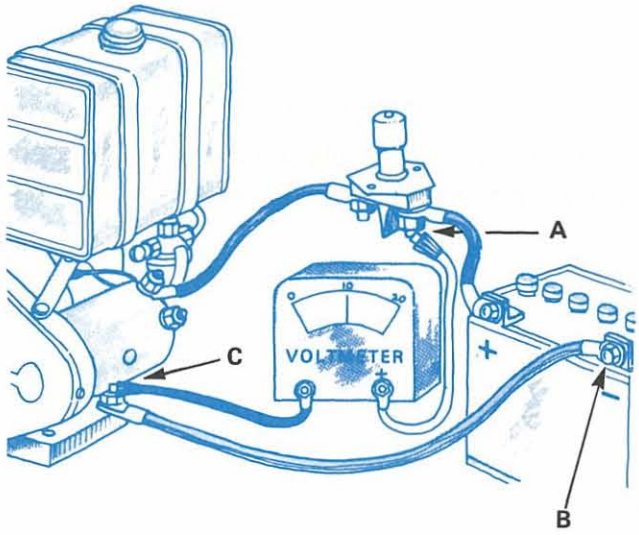
STEP NO. 1: BATTERY VOLTAGE GROUND CHECK

Figure 182

CAUTION:

This test is for a negative grounded system as shown. Some systems may be exactly opposite. The positive may go direct to ground instead of the negative. If this is the case, just reverse these procedures.

With the voltmeter connected, as shown in Figure 182, you should get a reading of, at least, 10 volts on a 12-volt battery. If the reading is less than 10 volts, it could indicate a poor ground connection in the system. Before proceeding further it would be necessary to check all connections to be sure they are clean and tight. The ground cable may be worn and need replacement. Corroded cables often cause this problem.

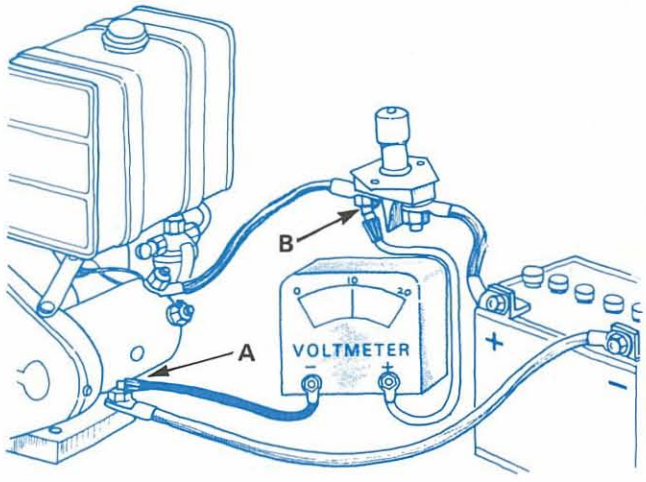


STEP NO. 2: CIRCUIT VOLTAGE CHECK BETWEEN BATTERY AND STARTER SWITCH.

Figure 183

If the voltage is still below 10 volts, check the circuit between the battery and the starter switch as shown in Figure 183. Be sure you connect the positive test lead to the terminal on the starter switch nearest to the battery shown at A. You should get a reading. If you get no reading or a low reading is obtained with this check, you could suspect the trouble to be some place between the negative terminal of the battery, as shown at B, and the ground of the starter as shown at C. It could also be between the cable connecting the starter switch and the positive terminal of the battery. Failure to get a good reading at this point would indicate trouble in one or both of these areas.

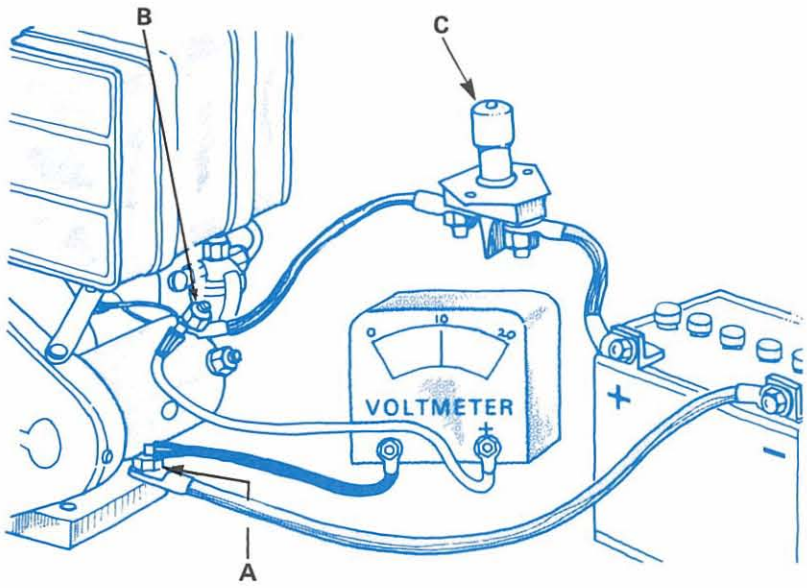
Connect the voltmeter as shown in Figure 184. Leave the negative lead attached to the starter ground as shown at A. Connect the positive lead to the starter switch in the position shown at B. This puts the switch between the meter and the positive terminal of the battery. In this position you should show no reading on the meter because the switch is open, and current cannot return to the positive side of the battery. If you do show a reading, it would indicate the starter switch is shorted and would need replacement. Now, turn on the starter switch and there should be a reading. If there is no reading, it would indicate there is an open circuit between point B on the switch and the positive terminal of the battery or an open circuit between point A and the negative terminal of the battery.



STEP NO. 3: STARTER SWITCH VOLTAGE CHECK

Figure 184

Next, check the circuit between the starter switch and the starter. Attach the voltmeter as shown in Figure 185. The negative lead of the voltmeter goes to the ground connection on the starter shown at A. Connect the positive lead to the armature post terminal of the starter as shown at B. You should not get a reading at this point because the starter switch is in the open position and there is no through circuit back to the positive terminal of the battery. Close the starter switch shown at C and you should get a reading on the meter and the starter motor should start running.



STEP NO. 4: CIRCUIT TEST BETWEEN SWITCH AND STARTER

Figure 185

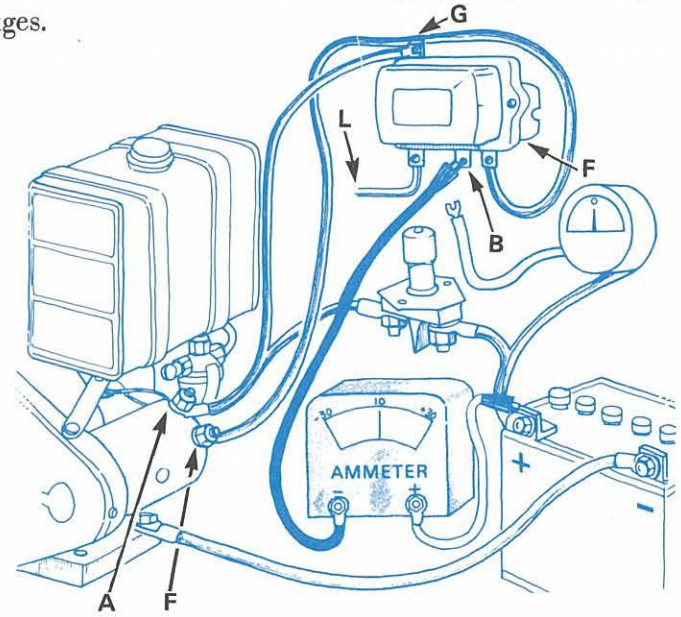
If the starter motor does not run and the voltage is satisfactory, this would indicate the starting motor is not operating properly and should be corrected by one of the procedures covered earlier on starter and generator repair.

If the starter motor does not work and there is little or no voltage, it would indicate a loose, broken or corroded connection between the starter switch and the point it is connected to the starter armature post shown at B.

TROUBLE SHOOTING D.C. GENERATOR CIRCUITS

Some generators or generator-starter units have a red warning light instead of an ammeter to tell if the generating system is working. This is particularly good for machine operators who are not accustomed to checking gauges such as the ammeter. Since most automobiles use the warning light system, very few people are accustomed to watching or reading gauges.

If the warning light comes on or the ammeter shows no charge while the engine is in operation you will have to determine if the trouble is in the generator or the regulator. The generating unit is checked with an ammeter. It should be a meter having a -30 to +30 amperage range. The first check is to disconnect the B lead from the regulator as shown in Figure 186. This puts the equipment ammeter out of the circuit. Notice when the equipment ammeter is disconnected from terminal B as shown, and the test ammeter is attached you have a connection from the negative side of the test ammeter to terminal B of the regulator. This is the same as when the equipment ammeter is connected to the positive terminal of the battery to terminal B of the regulator. We have just taken this equipment ammeter out of the circuit so the test meter can be used. With the test meter connected as shown, start the engine and run to a fast idle, about 1800 to 2200 RPM.



CHECKING GENERATOR CIRCUIT WITH AN AMMETER

Figure 186

LOW AMPERAGE READING

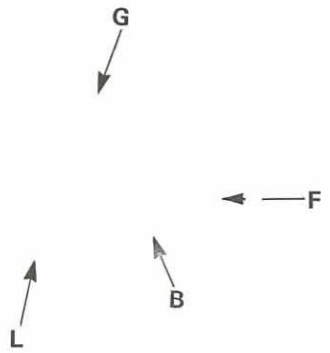
Check the test meter reading. If the charging rate is 5 amps or less it would indicate that trouble would be in the regulator. Before deciding the regulator is at fault, you should check for a loose drive belt. Excess play or a loose drive belt would tend to reduce the speed the generator is being driven and reduce its output.

All wiring connections should be checked as they will give the same indication of trouble.

If all wiring and belt tension checks are correct, it is then a good indication that the regulator needs replacement. Do not attempt to repair regulators. Most of them are sealed units and are not designed for repair except in well equipped shops specializing in this type work. Some engine service manuals may give instructions for adjusting regulators but most shops would be well off by not attempting this type of repair.

HIGH AMPERAGE READING

If the meter reading is in excess of 10 amps, disconnect the wire from terminal F on the regulator, as shown in Figure 187. This opens the generator field circuit and should stop the generator output from charging more than 10 amps. If the charging rate still remains above 10 amps, it would indicate trouble in the generator. There is a good possibility of a short in the field winding and the generator would have to be replaced or repaired with a new field coil.



CHECKING THE GENERATOR CIRCUIT WITH AN AMMETER

Figure 187

ZERO AMPERAGE READING

Leave the test meter connected as shown in Figure 187. Reconnect the field wire to terminal F. If the generator output is zero the regulator is very possibly defective. Next short the terminal F to ground with a jumper wire. The meter should show full charge of 10 amps or more since the regulator would be bypassed. This would further indicate a defective regulator. When terminal F is shorted to ground and there is no charge registered on the meter, it would indicate a defective generator.

SOLENOID SWITCH

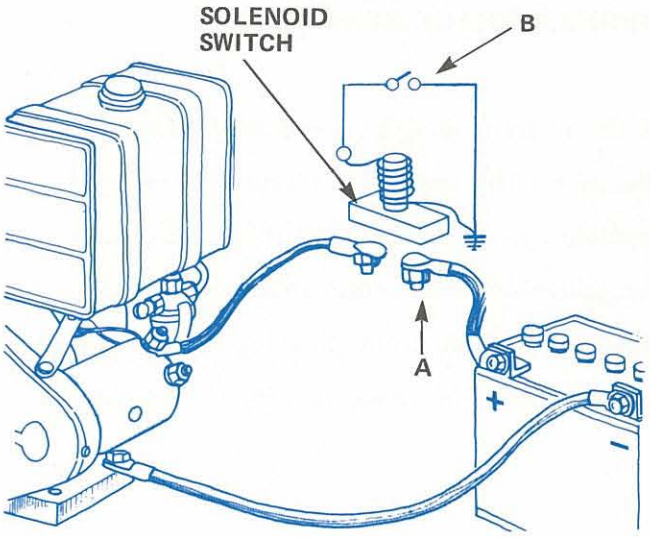


Figure 188

Another part of many starting circuits is the solenoid switch shown in Figure 188. The solenoid operates on the same principle of electromagnetism we studied earlier. When an electrical current is induced in a length of wire wrapped around an iron core it produces magnetism or a magnetic force.

In the case of a starting switch, as shown in Figure 187, it takes a heavy duty switch connected direct to the two wires going from the positive terminal of the battery to the starting motor. This type switch is satisfactory if the switch is located near the area of the starting motor and battery. However, if the switch were located several feet from the battery and starter it would be necessary to have an excessively long cable to connect the starter switch.

This cable is very heavy and has a high resistance so it is best to keep the cable to a minimum length. In many installations this is not practical. Years ago, this was the type starter switch used on most cars, but the switch was mounted on the floor as near to the battery and starter as possible. The modern trend is to incorporate the starter switch, lock and accessory circuit into one switch and have it conveniently located.

To eliminate using long cables a solenoid is used to activate a starter switch as shown in Figure 188. The solenoid switch actually makes the connection between the ends of the heavy battery cable shown at A. Notice the two small wires that supply current to the coil of the solenoid go directly to a switch shown at B. This switch is in the open position. When the switch is closed it activates the solenoid switch and makes the connection between the cables. When the switch at B is released a spring returns the solenoid switch to the open position.

ALTERNATORS AND RECTIFIERS

An alternator has the same basic function as the D.C. generators we studied earlier except they produce A.C. or alternating current instead of D.C. Since batteries are all D.C. they will only accept the charge from a generator giving direct current. Alternators are gradually replacing generators because they are more efficient in engineering design and produce better current regulation.

Automobiles have been moving from the generator system for several years, however, it has just been recently that small engines have started using some alternators. Actually the largest volume, by far, of all the small engines made are under 5 horsepower and use neither generator or alternator. We are covering the basic functions of each in this course so you will be familiar with their construction and function on larger engines you may have to service.

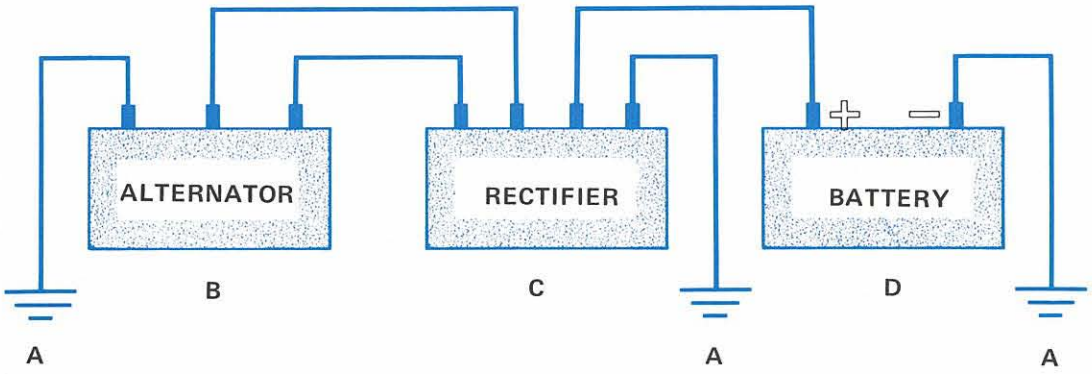
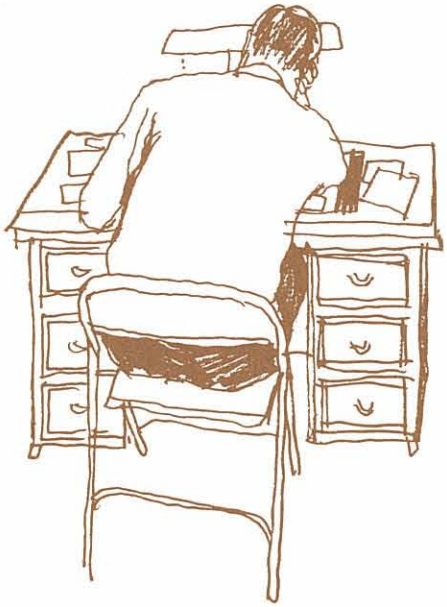


Figure 189

Figure 189 shows a basic wiring circuit for an alternator-generating circuit. We have an alternator, rectifier and the battery. Notice all three are grounded as shown at A. The alternator B supplies alternating current to the rectifier C. The rectifier changes alternating current to direct current that is used to recharge the battery at D. This wiring circuit is just an example and variations of this will often exist due to the specifications of the equipment it is to be used with and engineering design.

Both the alternator and the D.C. generator are used primarily with larger engines powering equipment needing self electric starters and other accessories, such as lights.



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(Leave Blank) GRADE(s)_____ _____

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- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

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1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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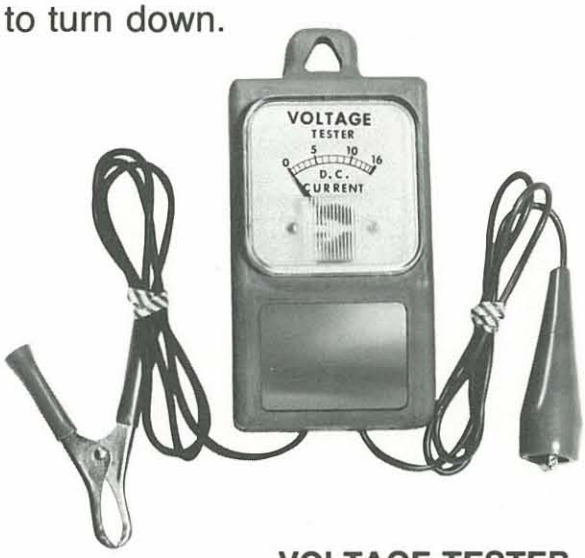

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EXAMINATION ON LESSON 20
BATTERY AND STARTER CIRCUITS

FOLEY-BELSAW INSTITUTE OF
SMALL ENGINE REPAIR
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NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. In making a circuit voltage check between the battery and the starter switch, the volt meter would be connected between the starter ground terminal and the starter switch. _____
   TRUE
   FALSE

2. A _____ is used to change alternating current to direct current. _____
   a. voltage regulator
   b. field coil
   c. rectifier

3. A generating unit can be checked with an ammeter. _____
   TRUE
   FALSE

4. If the generator output shows no reading, the trouble is very possibly in the regulator. _____
   TRUE
   FALSE

5. If a volt meter is used to check the battery, the negative lead of the meter must be connected to the negative or ground terminal of the battery. _____
   TRUE
   FALSE

6. The function of the generator is to charge the battery. _____
   TRUE
   FALSE

7. In making a battery voltage ground check, the volt meter would be connected between the ground terminal of the starter and the positive side of the battery. _____
   TRUE
   FALSE

8. A solenoid operates on the principle of _____. _____
   a. electromagnetism
   b. generator
   c. alternator

9. A _____ prevents the generator from over work and excessive output. _____
   a. rectifier
   b. regulator
   c. ammeter

(Continued on page 2)

10. The function of the starter is to supply power to turn the flywheel for starting the engine. _____
    TRUE
    FALSE

11. If the charging rate of a generator is 5 amps or less, it would indicate possible trouble in the regulator. _____
    TRUE
    FALSE

12. If the charging rate of a generator is above 10 amps it would indicate trouble in the generator. _____
    TRUE
    FALSE

13. A _____ is used to prevent the battery from receiving an excess charge. _____
    a. regulator
    b. generator
    c. alternator

14. An alternator produces _____ current. _____
    a. ac current
    b. dc current
    c. neither of the above

15. If a battery receives an excess charge, it will become hot. _____
    TRUE
    FALSE

16. The amp meter is used to tell the operator what the _____ is doing. _____
    a. generator
    b. rectifier
    c. field oil

17. Identify the reference numbers for the parts or connections as they relate to Fig. 20-1.
    ground wire _____
    starter/generator _____
    voltage regulator _____
    starter switch _____
    amp meter _____
    positive battery terminal _____
    negative battery terminal _____
    field coil terminal _____
    generator armature terminal _____

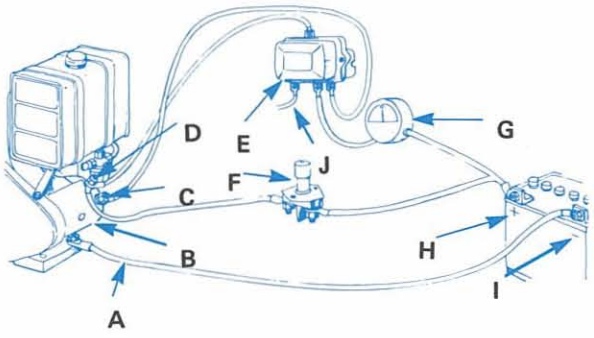


Figure 20-1

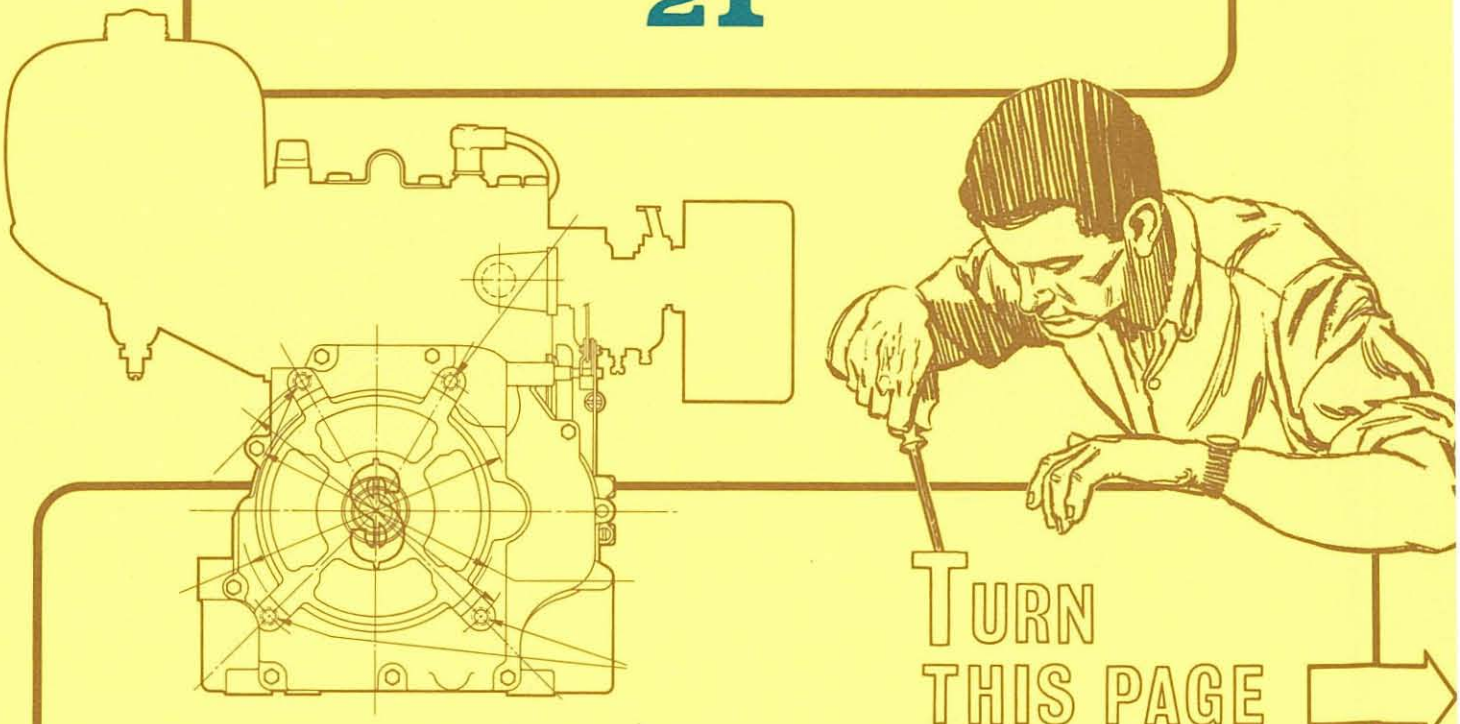
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

21



TURN THIS PAGE

...and let's find out all about -- **BATTERIES**

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LEAD-ACID CELL

The purpose of the battery in an internal combustion engine is to provide a source of power to crank the engine and provide the necessary electrical energy for the ignition system for battery ignition electrical systems.

Lead-acid batteries, often called storage batteries, are not a storage tank for electricity as the name would imply. It is a device for converting chemical energy into electrical energy or power. The amount of electrical energy in a storage battery is determined by the amount of chemical substances in the battery and their condition.

It won't be necessary to go into the complete chemical function that takes place in a battery. In order to service engines it will, however, be necessary to know some of the basic principles of battery construction. A lead-acid storage battery contains metallic lead grids of a positive and negative chemically treated material. These grids or plates as they are known in a lead-acid storage battery are contained in a tank or container containing a mixture of water and sulfuric acid. The combination of these negative and positive plates, with the sulfuric acid and water, create a chemical action that produces electricity.

Figure 190 shows the basic principle of this type battery when it is being used or in the discharging condition. As we mentioned earlier in the course, direct current flows from negative to positive. The negative plate at A shows current flowing from the negative side, through the resistance, which is the light, and then to the positive side shown at B.

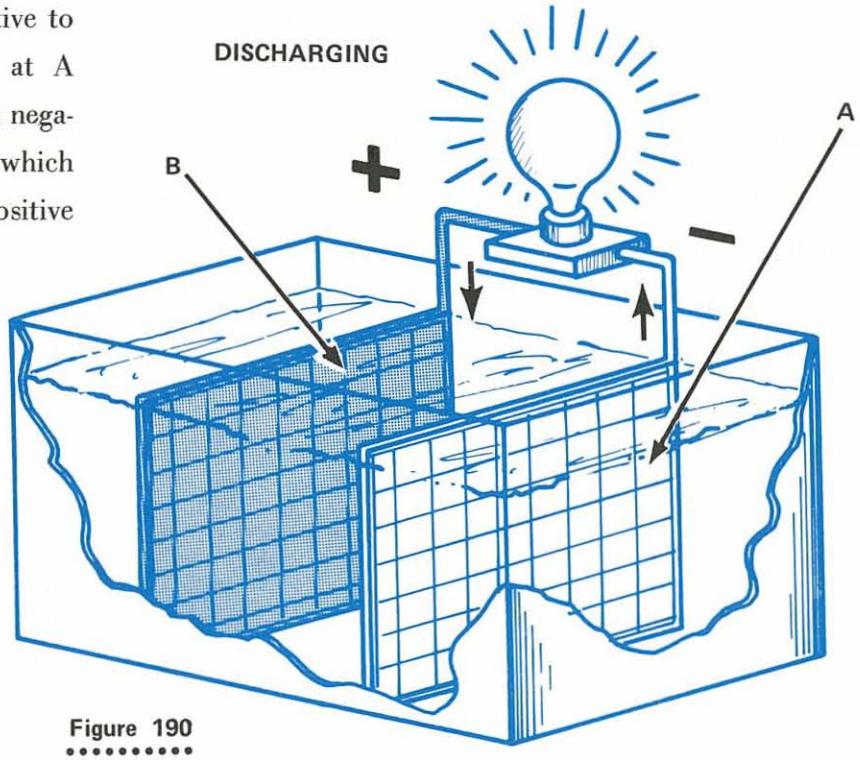


Figure 190

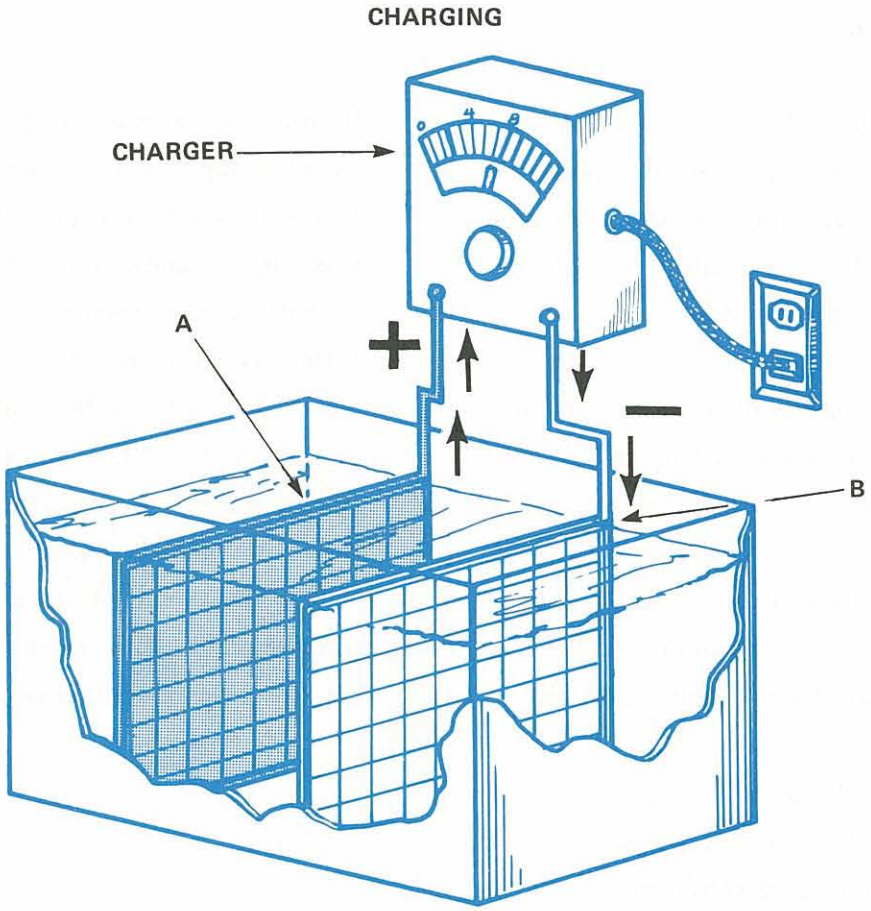


Figure 191

If this condition were permitted to continue long enough the chemical action of the battery would soon be exhausted, however, the battery can be recharged by reversing the chemical action as shown in Figure 191.

A battery charger, as shown in Figure 191, can be used to recharge the battery or, in operation, the generator or alternator performs this function. Notice the current flow has been reversed so it is flowing from positive to negative. The charger is causing the flow from the positive plate at A to the negative plate at B.

Figure 190 and Figure 191 show the basic principle of a single cell of one battery. Earlier we mentioned that a cell would deliver 1.5 volts. This rating is for a dry cell type battery and does not apply to the wet cell lead-acid battery. The average voltage for this battery is two volts for each cell.

LEAD ACID BATTERIES

So far we have been talking about only the cell of the battery. As cells are added the battery voltage increases. Earlier we studied the principle of the series circuit. By adding cells connected in series we increase the voltage. Each cell has a negative and positive terminal and when they are connected in series as shown in Figure 192 we have a 12-volt battery.

The negative terminal is shown at A and the positive terminal is at B. Notice how the positive and negative terminals are connected at C. Since we have six complete cells contained in this battery and each delivering two volts, we have a 12-volt battery.

Each individual cell, as shown at D, is enclosed in a hard rubber or plastic individual case. All of the cells are then enclosed in a larger case, shown at E. The connecting plates, shown at C, are generally inside the cover and not noticeable from the outside. Many older batteries had these connecting plates on the outside.

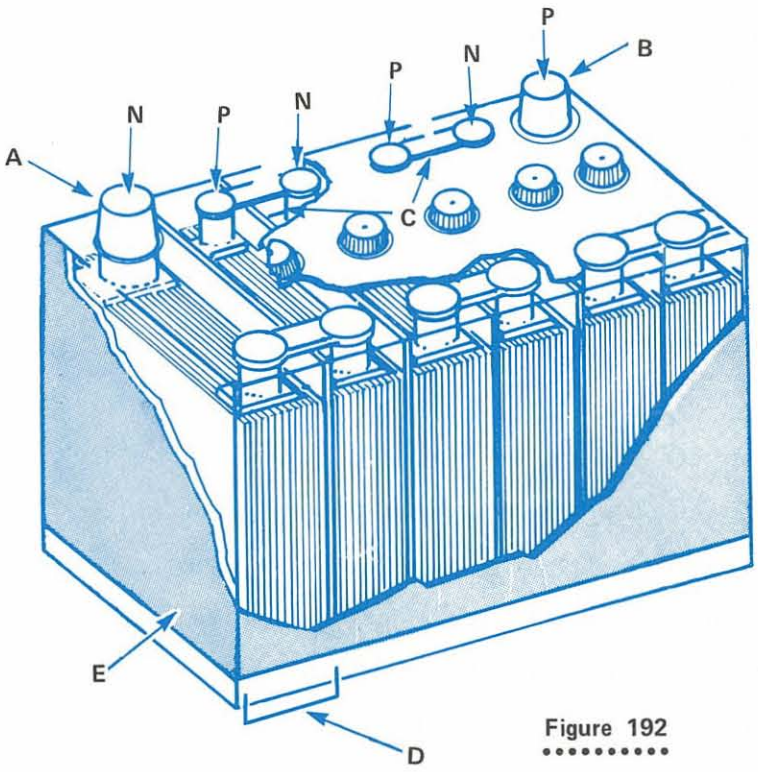


Figure 192

LEAD-ACID BATTERY RATINGS

The size of a battery is usually expressed in ampere-hours. If a battery is capable of delivering 5 amps for 20 hours it is classified as a 100-amp hour battery. The 20 hour discharge period is sometimes not mentioned but implied when it is referred to as a 100 amp-hour battery. This battery rating is very important when selecting a battery for a particular application.

The chemical action of a battery is closely related to temperature. Extreme cold reduces the amp-hour rating of batteries and warmer temperatures increase the amp-hour rating. Batteries used in cold weather applications on heavier equipment require a much higher amp-hour rating than those used with smaller equipment in warmer temperatures.

BATTERY LIQUID

The liquid in the battery consists of water and sulfuric acid and is called the electrolite. It consists of 36 per cent sulfuric acid and 64 per cent water. The sulfuric acid does not need to be replaced unless it has been lost through leakage or spilled from the battery. Water is lost through evaporation and chemical action within the battery while it is being charged. When this happens some of the water in the electrolite is changed to hydrogen and oxygen gases. These gases pass through the vent holes in the battery caps. Water must be added to compensate for the evaporation. This is very important as the tops of the plates must always be covered with the electrolite solution.

Every cell of the battery should be filled with water separately as they are sometimes separated. Use distilled water if possible since it contains less impurities and foreign matter that can shorten the life of the battery. If distilled water is not available, fill each cell to the fill level with clean water.

Figure 193 on the next page shows the recommended way to fill the battery. In many batteries the vent well, shown at A, extends into the battery far enough for the lower end, shown at B, to serve as a fuel level indicator. Batteries without this arrangement are filled to about 1/2-inch above the top of the separations. Sometimes these separations are hard to see. You can be safe by filling to a point about 3/4-inch below the bottom of the cap screw threads shown at C.

Avoid overfilling. If the liquid level is too high, the electrolite will overflow through the vent holes in the caps because the liquid will expand slightly when the battery becomes warm. If the electrolite is allowed to overflow it should be washed with water immediately since it can come in contact with the battery terminals and the frame. Since this liquid is a conductor it will provide a path for leakage of the electricity. It also will cause fast corrosion and deterioration.

CAUTION:

Battery acid is very dangerous and can cause severe burns and blindness if it comes in contact with your eyes. Battery acid is highly soluble with water so use plenty of water if you are exposed to direct contact with acid. Apply baking soda or lime as they will neutralize the acid.

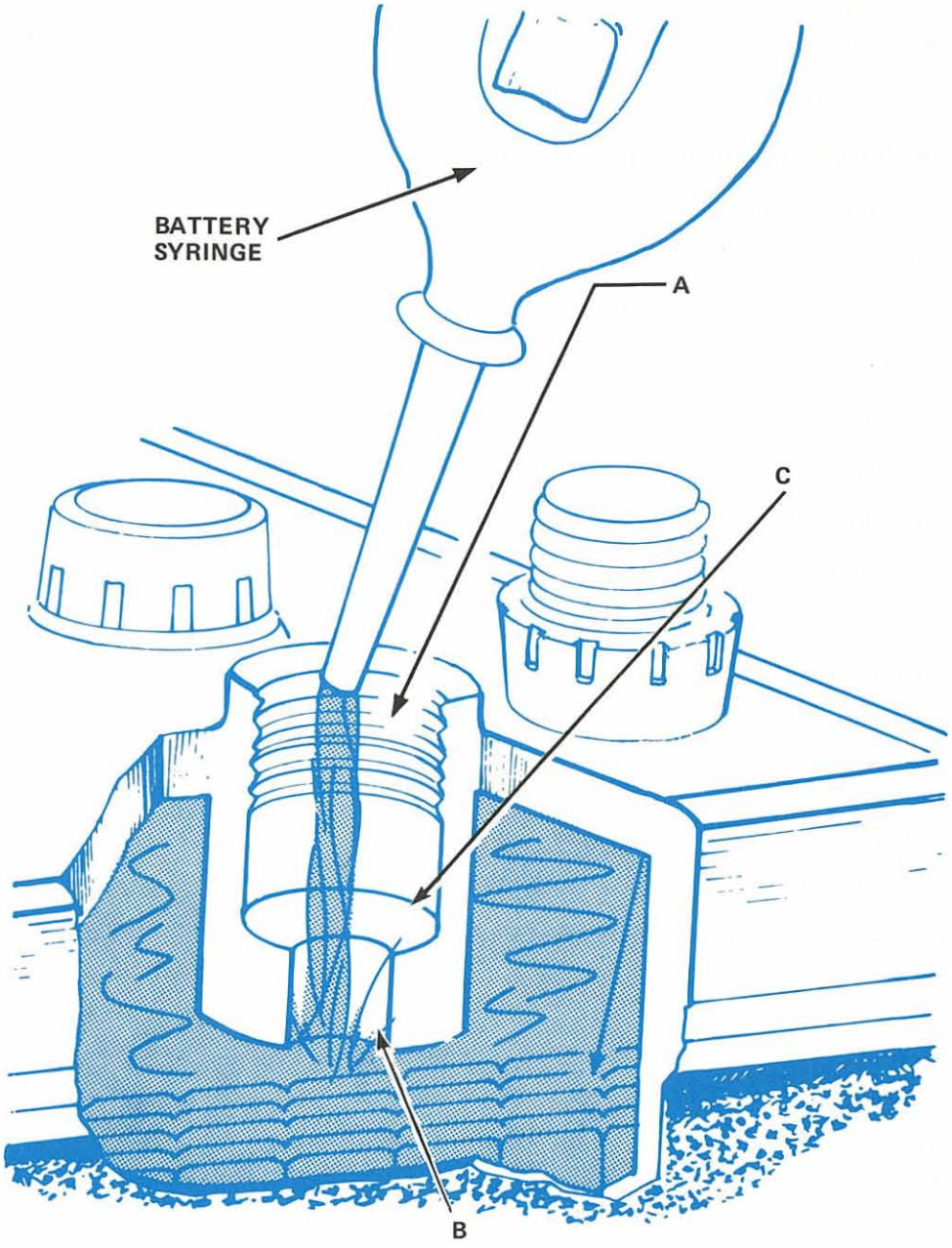


Figure 193

It is important to check the vent holes in the battery. If they are allowed to plug up, pressure can develop inside the battery and cause it to break the seal of the case.

HYDROMETER TEST

The hydrometer or the voltmeter are the only methods recommended for testing the condition of batteries. Never use the short circuit method to see if a battery has power. A short circuit is a direct short across the negative and positive terminals to see if the battery has spark. Not only does this quickly discharge the battery but it is dangerous. A battery will produce hydrogen gas and sometimes it will collect around a battery. Hydrogen gas is explosive and a spark could easily cause an explosion.

The condition of a battery is dependent on the strength of the electrolite. A hydrometer can be used to test the specific gravity of the electrolite. Specific gravity is the weight relationship between an equal amount of water and another liquid. If a liquid, other than water, has a specific gravity of 2.567 it means the liquid is 2.567 times as heavy as an equal volume of water at the same temperature.

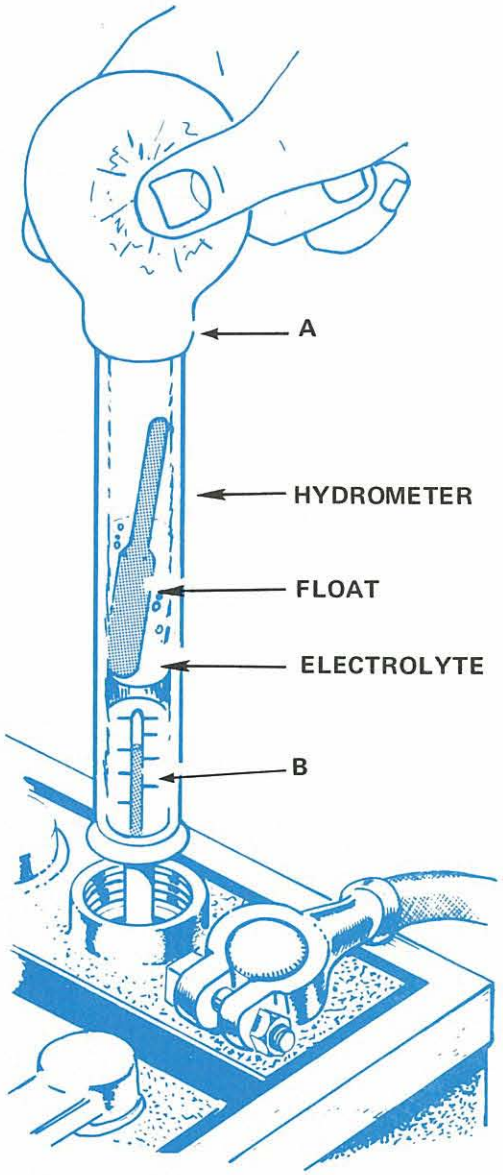


Figure 194

To use the hydrometer in checking the condition of a battery it is first necessary to have the level of the electrolite above the separators in the battery. If the level is below it will be necessary to add water and operate the engine for several hours before the water and sulfuric acid are thoroughly mixed. Insert the hydrometer nozzle as shown in Figure 194. Compress the bulb A and slowly release to draw electrolite into the tube. Some hydrometers also have a thermometer as shown at B. The reason for this is that specific gravity will change slightly with temperature.

Adjust the electrolite in the tube until the float rides free. If the float tends to stick to the side of the tube, shake it sideways gently. It may be necessary to clean out the inside of the tube with fresh water.

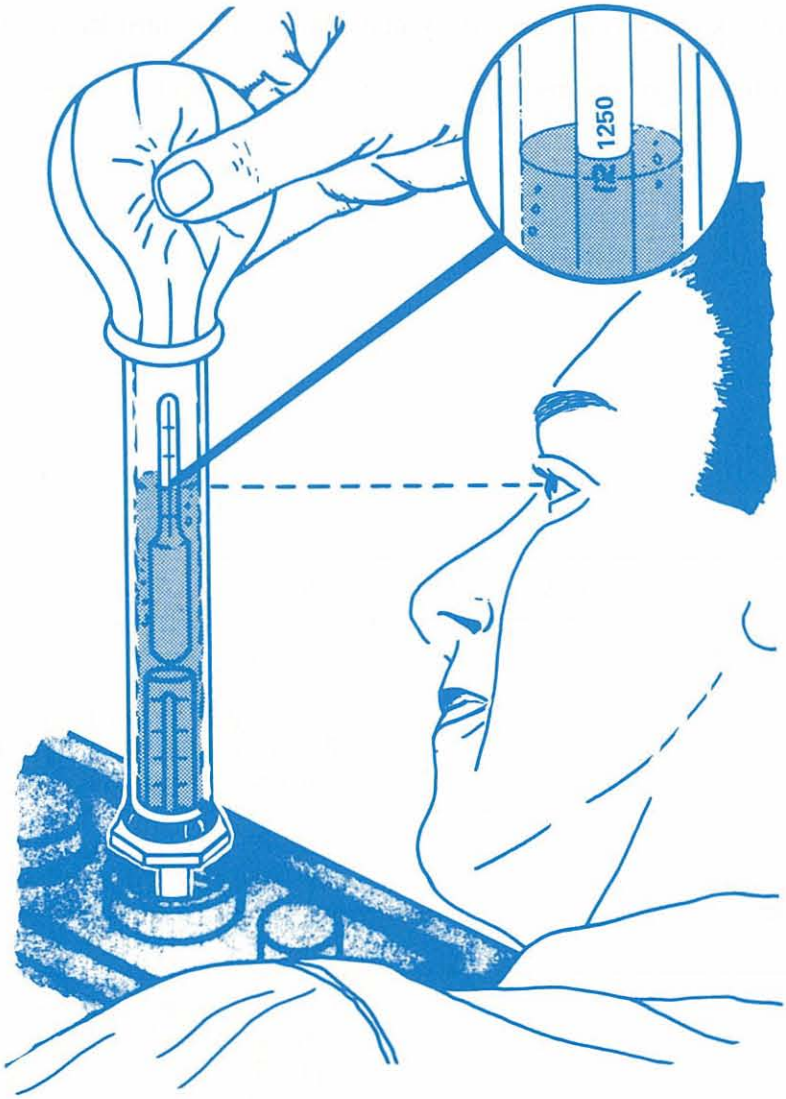


Figure 195

Leave the hydrometer nozzle in the battery while taking the reading. Adjust the position so you can take a direct reading without looking down at an angle which will give you a false reading. Figure 195 shows the correct position for reading.

Generally it is not necessary to take the temperature when checking a battery with a hydrometer. You should, however, allow for extreme cold or hot temperatures. About 80 degrees is the ideal reading temperature and, as a general rule, you can add .004 for each 10 degrees above 80 degrees or subtract .004 from each 10 degrees below 80 degrees Fahrenheit. The ideal specific gravity reading for a good battery is 1.280.

The reason for these temperature adjustments is that, as the temperature goes up, the electrolite. expands and is not as dense as it was at 80 degrees. As the temperature goes down, it is more dense and will weigh more.

By making the corrections on your readings they would be the same as a reading taken at 80 degrees Fahrenheit. Always check every cell in a battery individually and return the electrolite back to the same cell. After using, flush the hydrometer with clean water. Interpret the readings from the check chart shown in Figure 196.

INTERPRETING SPECIFIC GRAVITY READINGS	
Specific Gravity Reading	Meaning
1.300	Electrolite contains too much sulfuric acid. Electrolite has been added instead of water. Battery is being overcharged.
1.250 (minimum) 1.280 (maximum)	Battery in good condition. Some batteries are fully charged at 1.250. Batteries intended for use in warmer climates may be fully charged at 1.250.
1.225 (or less)	Battery charge too low. Electrolite in the various stages shown below will start to freeze. Specific Gravity — Temperature 1.250 — –62 degree F. 1.200 — –16 degree F. 1.150 — + 5 degree F. 1.100 — + 19 degree F.
After charging check each cell individually. If there is a difference of over 50 points between the highest and the lowest cell reading.	Battery may need to be replaced. Always check warrantee. Condition can indicate short circuits in the battery, unequal loss of acid in the individual cells, breakdown of separators or accumulation of impurities.

Figure 196

VOLTMETER TEST

The hydrometer test is by far the most complete test to show the actual condition of the battery. A voltmeter can also be used to tell the condition of the battery, however, it does not tell a complete story. It will only tell you if the battery is in need of recharging or if it is below its rated voltage. This condition could be due to the generator not charging the battery or it could mean the battery is not receiving a charge and is defective.

When testing a battery with a voltmeter, first disconnect the spark plug wire to prevent the engine from starting while the test is being made. Connect the voltmeter to the battery as shown in Figure 197. Be sure to connect the positive lead of the voltmeter to the positive post of the battery and the negative lead of the meter to the negative post of the battery.

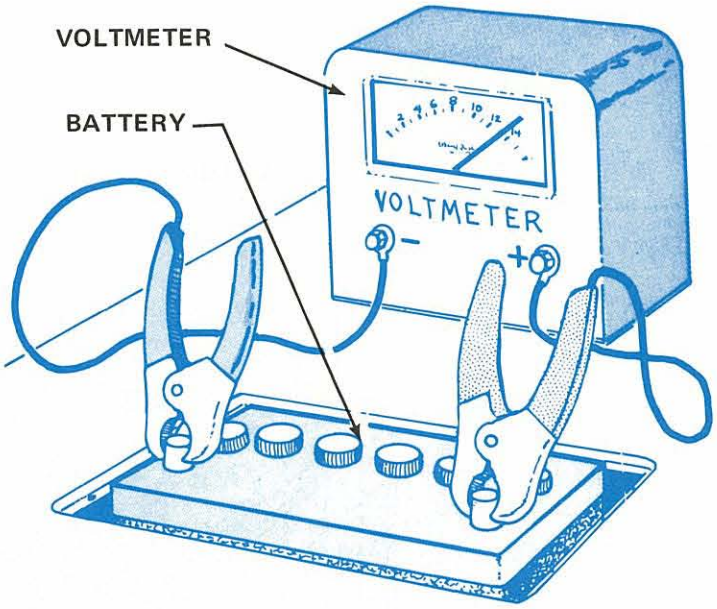


Figure 197

Hold the starter switch on just long enough to get an accurate reading on the voltmeter. Do not hold over 5 or 10 seconds to ease the load on the battery and keep from overheating the starting motor.

If the voltage is less than 9 volts for a 12 volt battery and less than 4 volts for a 6 volt battery, it would indicate the battery needed charging or it is defective. Actually all the voltmeter tells you is that the rated voltage is or is not present in the battery at the time of checking.

BATTERY MAINTENANCE

The battery liquid level should always be maintained above the top of the plates. When parts of the plates or separators are exposed to air they dry out. After a part has become dry, it loses its ability to function fully. This causes the battery to lose much of its capacity and cranking power. It also means shorter battery life.

Since only water will evaporate, it causes the sulfuric acid part of the electrolite to become very strong. This has a tendency to break down the plates and the separators as shown in Figure 198. This shows a typical cell group. The negative plate group is at A and the positive group is at B. The separator plates dividing the negative and positive plates are shown at C. The liquid level must always be maintained above these plates.

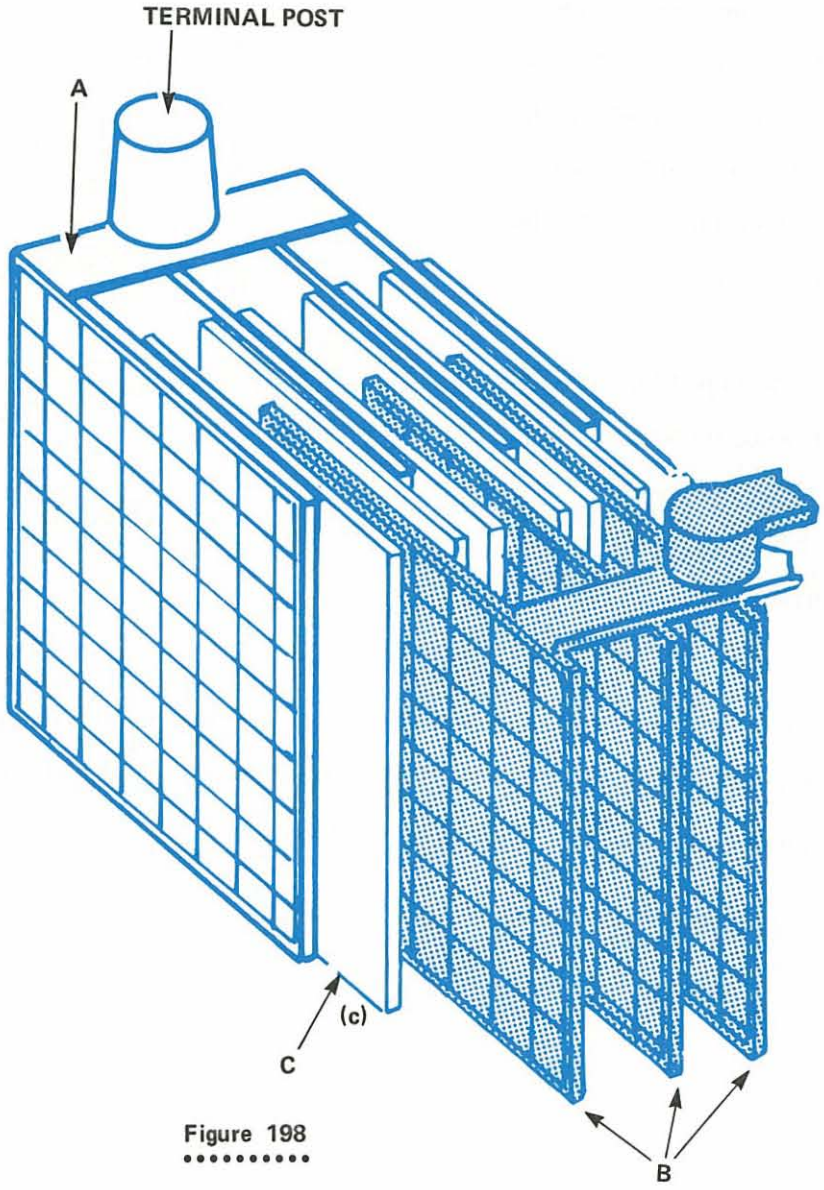


Figure 198

Batteries will require more water when they are being overcharged and when the weather is hot. Batteries lose much more water through evaporation in hot weather than cold weather. It is important that batteries remain at near or full charge. When a battery remains discharged for several weeks the lead sulphate on the plates becomes hard. This prevents them from taking a full charge and they can become permanently damaged.

Temperature has a great deal to do with the operation of a battery. A fully charged battery will only be about 40 percent efficient at zero degrees Fahrenheit. This is the reason there are battery failures in winter than in warmer weather. A battery exposed to low temperatures can have almost 100 percent of its starting power if it is attached to a battery charger because the charger generates heat in the electrolite giving it almost the same efficiency as warm weather.

Cleaning a battery is very important since dirt, acid and moisture collect on the top and can actually short across the battery terminals. A corrosion will occur at the terminals and if allowed to remain and accumulate it will insulate the battery cables from the terminals.

Corrosion and dirt on top of a battery can actually be measured with a meter at points across the top of the battery. This leaves the battery in a continuous state of discharge. The discharge rate may be very low but if it continues and is left without charging for a few days it will actually run the battery down.

The best method of cleaning a battery is to use plain baking soda and water. First wet the battery with water. Then spread on about 1/2 cup of baking soda. It will begin a boiling action. Let it stand for a few minutes and rinse the battery with clean water. Repeat this operation two or three times. After the battery is dry, sprinkle a small amount of soda on the terminals.

To properly service a battery the terminals should be removed from the battery post. Sometimes these terminals are hard to remove because of corrosion. Permanent damage to the terminal post and the battery can occur if you are not careful in removing the cables.

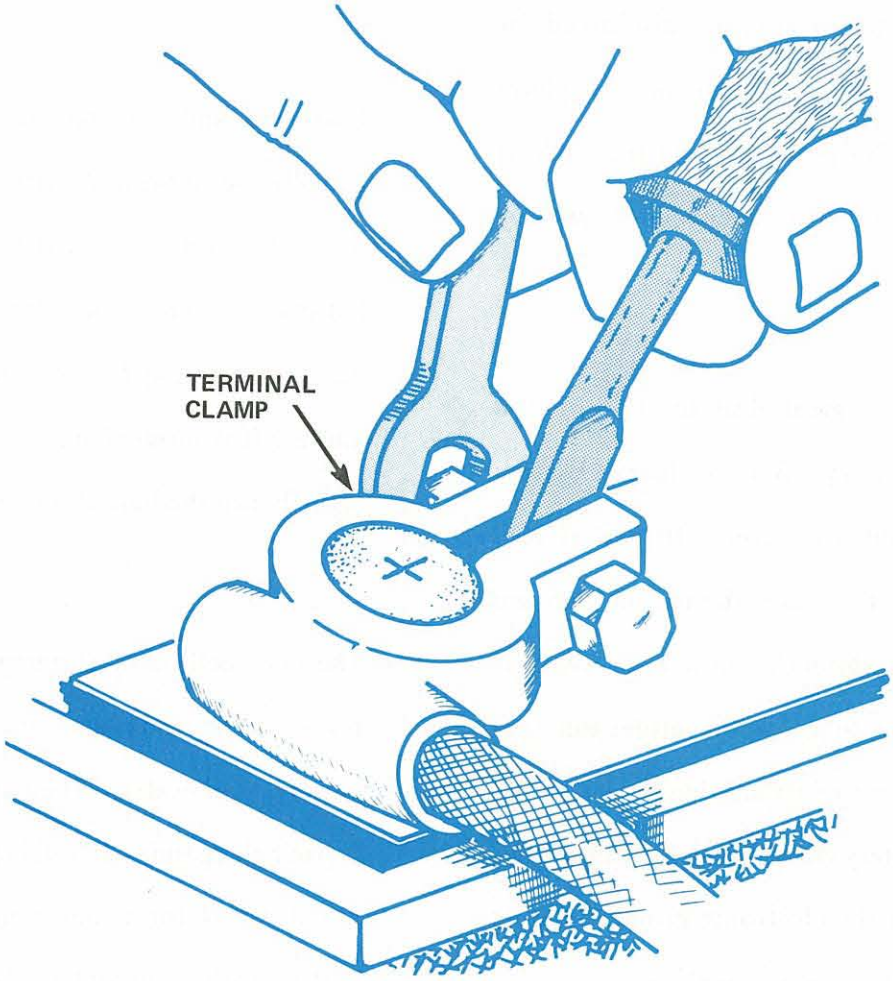


Figure 199

Figure 199 shows the first step. Loosen the bolt and nut, then spread the terminal connector apart with a screwdriver as shown. In most cases the cable will come off. If it has been badly pitted and corroded it may be necessary to use a battery terminal puller as shown in Figure 200. This procedure is seldom necessary, especially if the terminals are cleaned properly before trying to remove the cables.

Generally the cables will be just long enough to reach the proper battery terminal, however, if the battery is removed, be sure to make a note so it will be installed the same way it came out with the proper cables going to the terminal. Reversing the terminals could do serious damage to other parts of the electrical system.

Clean all cable clamps and terminals with a wire brush along with the top of the battery. Many repair shops like to use a coating of petroleum jelly such as Vaseline on the post and clamps.

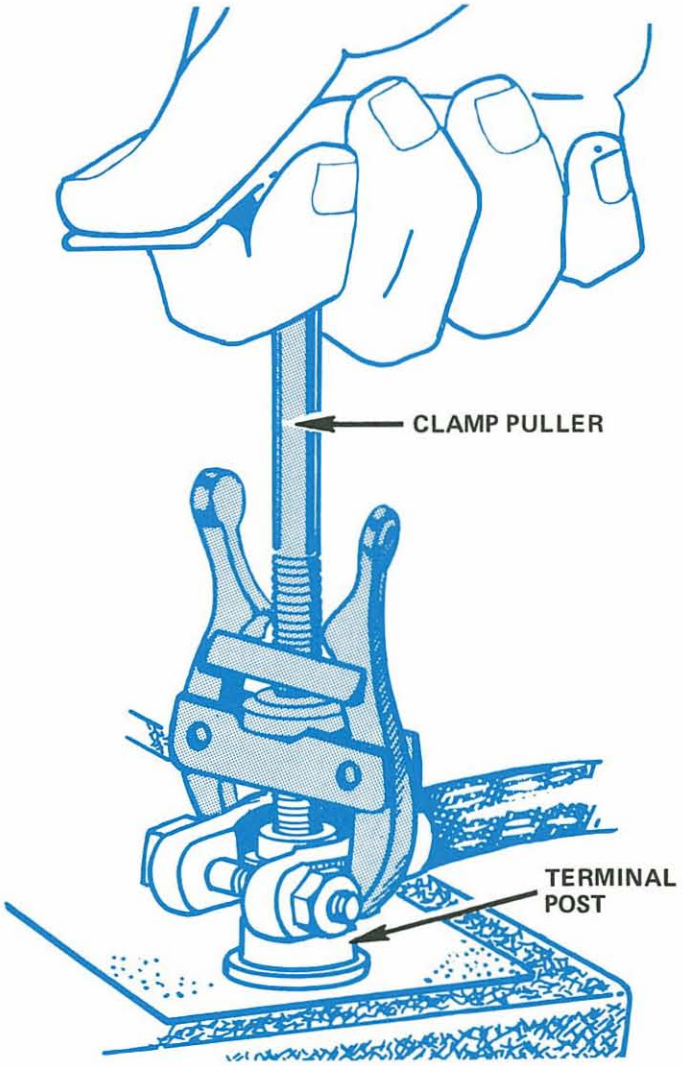
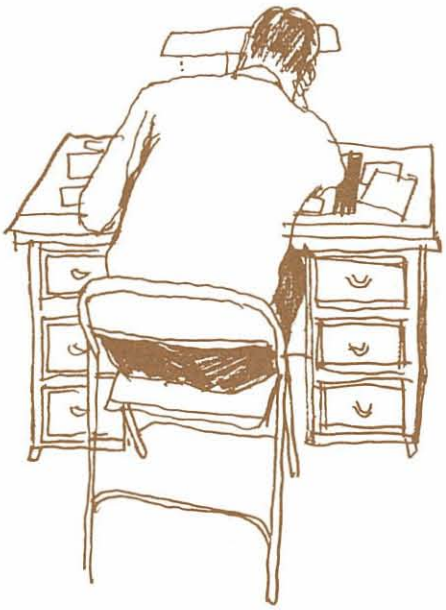


Figure 200

NICKLE CADMIUM BATTERIES

Nickle cadmium batteries are generally used only for starting purposes. They are sealed, self-contained and recharged from a battery charger operating from regular 110 volt house current. This charger, known as a trickle charger, is used when the battery is not in operation. It can be left on continuously. The charger converts regular A.C. house current to D.C. current through a rectifier. These batteries are not repairable and require only recharging between operations. They can generally be recharged in 12 to 14 hours.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 21
BATTERIES

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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The hydrometer is used to check the _____ of the electrolite. _____
   a. water
   b. acid
   c. specific gravity

2. The grids or plates in a lead acid storage battery are contained in a mixture of water and sulfuric acid. _____
   TRUE
   FALSE

3. Nickle cadmium batteries are recharged by the use of a battery or trickle charger. _____
   TRUE
   FALSE

4. A lead acid battery is a device for converting chemical energy into electrical energy. _____
   TRUE
   FALSE

5. Extreme cold reduces the _____ rating of a battery. _____
   a. voltage
   b. power
   c. ampere
   d. all of the above

6. Specific gravity will not change with temperature. _____
   TRUE
   FALSE

7. The amount of electrical energy in a storage battery is determined by the amount of chemical substances in the battery and their condition. _____
   TRUE
   FALSE

8. Specific gravity is the weight relationship between an equal amount of water and another liquid at the same temperature. _____
   TRUE
   FALSE

9. A battery is recharged by reversing its mechanical action. _____
   TRUE
   FALSE

(Continued on page 2)

10. A volt meter will only tell if the battery is below its rated charge. _____
    TRUE
    FALSE

11. The liquid in a battery is called the _____. _____
    a. specific gravity
    b. electolite
    c. hydrogen gas

12. A battery can produce _____ that can collect around the top of the battery that is explosive. _____
    a. hydrogen gas
    b. sulfuric acid
    c. electrolite

13. The sulfuric acid in a battery will evaporate along with the water. _____
    TRUE
    FALSE

14. The size of a battery is usually expressed in _____. _____
    a. amp hours
    b. volts
    c. can be both of the above

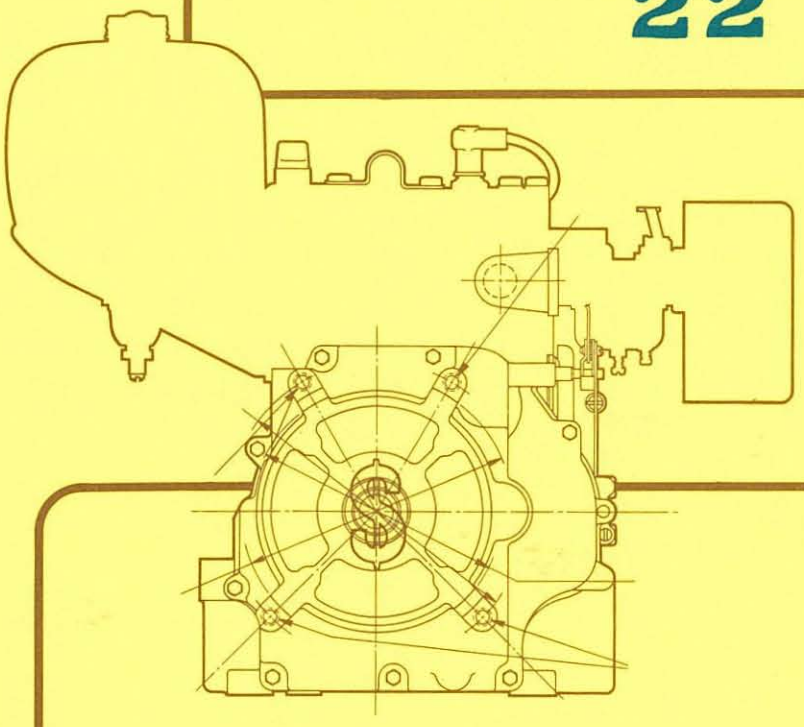
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

22



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IGNITION THEORY

The purpose of the ignition on any spark-ignition engine is to provide a spark of the proper strength to the spark plug at the exact time. These are the two functions of the ignition system. Both the intensity of the spark and the proper timing have to be coordinated so they will ignite the fuel-air mixture in the combustion chamber at the proper time.

There are three basic types of ignition systems. The battery system is the source of electrical current obtained from a chemical action. On the magneto system the source of current is obtained from a mechanical action. In either case, the electrical current used to ignite the spark plug must be of sufficient high voltage to jump the spark plug gap.

The third type of ignition system is actually a variation of both the battery and the magneto system. It's called solid-state ignition. Solid-state ignition can be used with either system. Actually, solid-state is just a matter of distribution of electrical current. In both the battery and the magneto systems the electrical distribution is accomplished by the mechanical function of the breaker point assembly.

Solid-state ignition does not have a breaker point assembly. This function is performed by an electrical circuit. We'll go further into solid-state ignitions later after we have covered the other two systems which have been used for many years. Solid-state is just coming into the small engine field and is relatively new. It may be sometime before it becomes more popular because of the price.

MAGNETO IGNITION SYSTEM

The magneto ignition system is widely used on small engines because they are easily adaptable since most of them require no other electrical load other than the spark for igniting the fuel. The magneto produces its own electricity without the help of a generator or battery.

The magneto system, in addition to the magneto function to produce electricity, has three other basic components it works with. They are spark plugs, points and the condenser. We'll cover the function of each of these as they fit into the system.

There are actually two types of magnetos, internal and external. Both operate on the same principle. The flywheel magneto is the one most commonly used on small engines. Figure 201 shows a cut-away view of a typical flywheel magneto.

Earlier in studying electricity, we learned that electricity could produce magnetism and magnetism could produce electricity. All that is necessary is to pass a wire through a magnetic field or pass the magnetic field around the wire and electricity would be produced.

FLYWHEEL TYPE MAGNETO

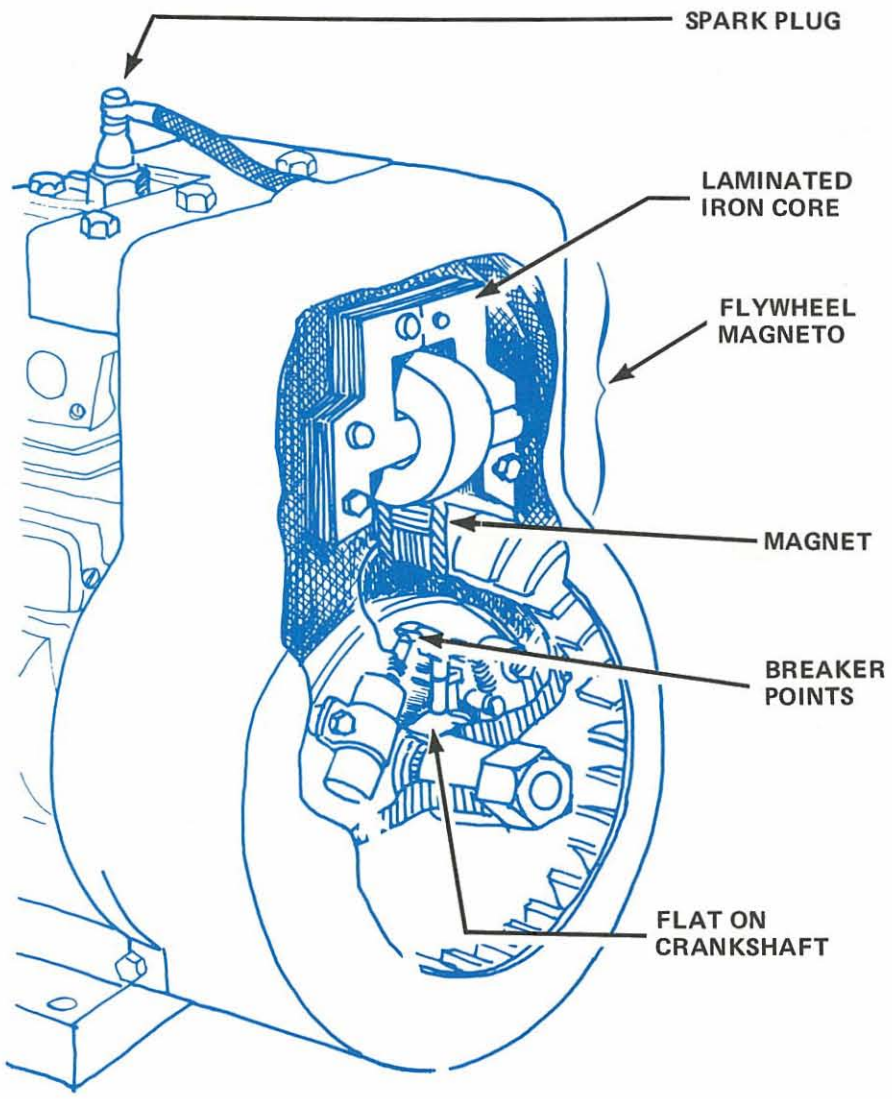


Figure 201

PRINCIPLES OF MAGNETISM

Before we go further into magneto ignition it will be necessary to go further into the basic principles of how electricity is produced this way and how voltage can be changed to meet different needs.

Magnetism creates imaginary lines of force. They cannot be seen, felt or heard but they are there. These lines of force extend from the north pole of the magnet to the south pole of the magnet and through the length of the magnet.

Figure 202 shows a typical magnet and its lines of force. The forces go from N (north) to S (south) as shown by the arrows. These lines of force are known as the magnetic field. When we pass wire through this magnetic field, or if we pass the magnetic field past wire, an electric current will be induced in the wire.

The magnetic forces shown in Figure 202 come from a permanent magnet. This type magnet creates a magnetic field at all times. There are other types of magnets that create magnetism only when current is induced around an iron core. This is the type of magnetic action produced to operate a solenoid. As soon as the electrical current is stopped the core no longer has a magnetic field. A magneto uses a permanent type magnet.

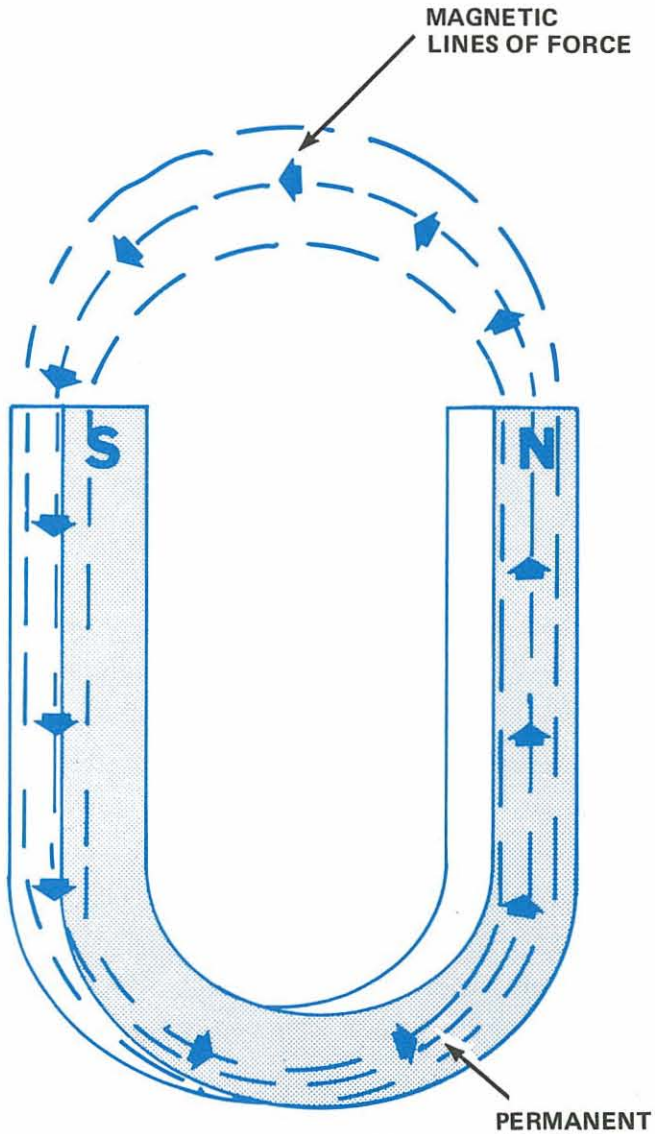


Figure 202

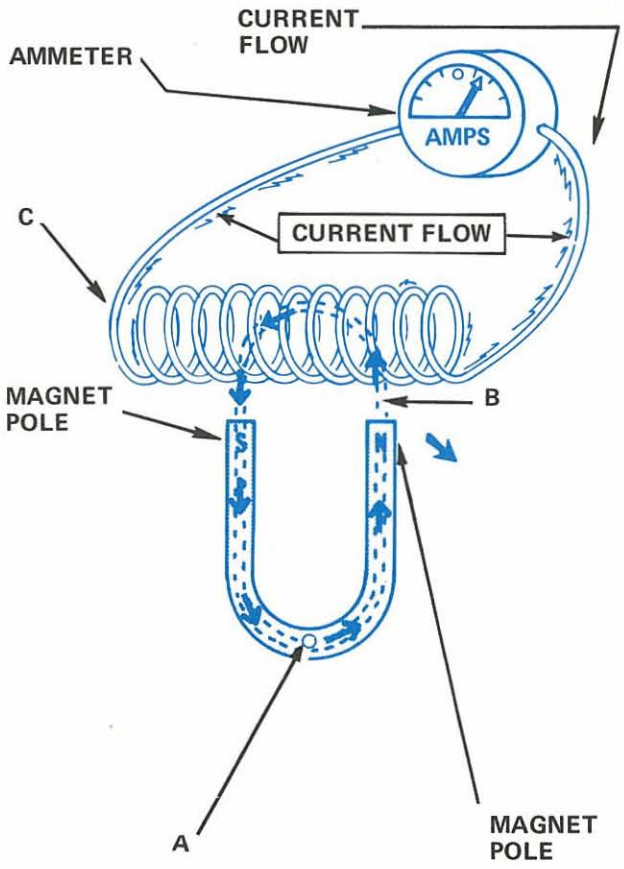


Figure 203

Figure 203 shows a simple generator. The permanent magnet will pivot in a 360 degree circle, as shown at A. The north and south pole of this magnet create the magnetic field shown at B. Every time the magnet passes the closed conductor coil of wire, shown at C, it creates a flow of current that will register on an ammeter because the lines of force are cut by the coil.

Notice we have called this a simple generator because this is just part of the magneto. This generator part of the magneto is creating electricity but of such a low voltage that it would not jump the spark plug gap to ignite the fuel.

The amount of current that can be produced from a simple generator working on this principle depends on the number of turns of wire in the coil at C, the intensity of the magnetic field shown at B, and the speed at which the magnetic lines of force pass by the coil.

To develop the voltage necessary to jump the spark-plug gap, it is necessary to have another electrical circuit to increase the voltage. Voltage can be decreased or increased by running it through a transformer. The combination of a generator and transformer make up the basic components of a magneto.

TRANSFORMER PRINCIPLES

A transformer is made up of two coils of wire wound together, one on top of the other, as shown in Figure 204.

One coil is called the primary coil and the other

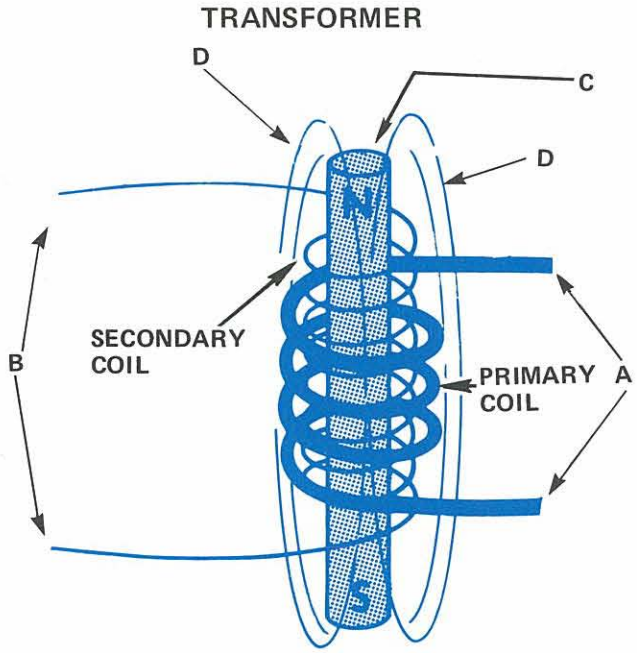


Figure 204

the secondary coil. The lead ends of the wire forming the primary coil are shown at A. The secondary circuit leads are at B. Notice both of these circuits are wrapped around an iron cord shown at C. The transformer primary circuit shown at A is supplied with current from the low voltage generator shown in Figure 203. This is the low voltage or input side.

When the transformer primary circuit is supplied with current it sets up a magnetic field around the primary coil. This causes the iron core, shown at C, to become magnetized and establishes additional lines of force as shown at D.

The relationship between the number of coils and the voltage applied to the primary is directly proportional to the number of coils of the secondary and the voltage the secondary will produce.

If the primary coil, shown at A, had 100 turns or coils of wire and an applied voltage of 15 volts and the secondary coil had 200 coils the voltage produced at the secondary circuit at B would be 30 volts. This would be a step-up transformer since the 15 volt input has been stepped up to 30 volts.

Transformers can also lower voltage by this same formula of relationship between the number of coils. If we just reverse these coil windings we can reduce the output voltage. If the primary coil had 200 turns and 15 volts applied to the primary circuit and the secondary circuit had 100 turns the output would be only 7-1/2 volts. The actual number of turns of wire on the coil mentioned here is simply used as a relative example.

A magneto operates on the principle of combining the generator or current producing unit with a transformer. The combination of these two principles into one unit will produce the high voltage necessary to ignite the spark plug.

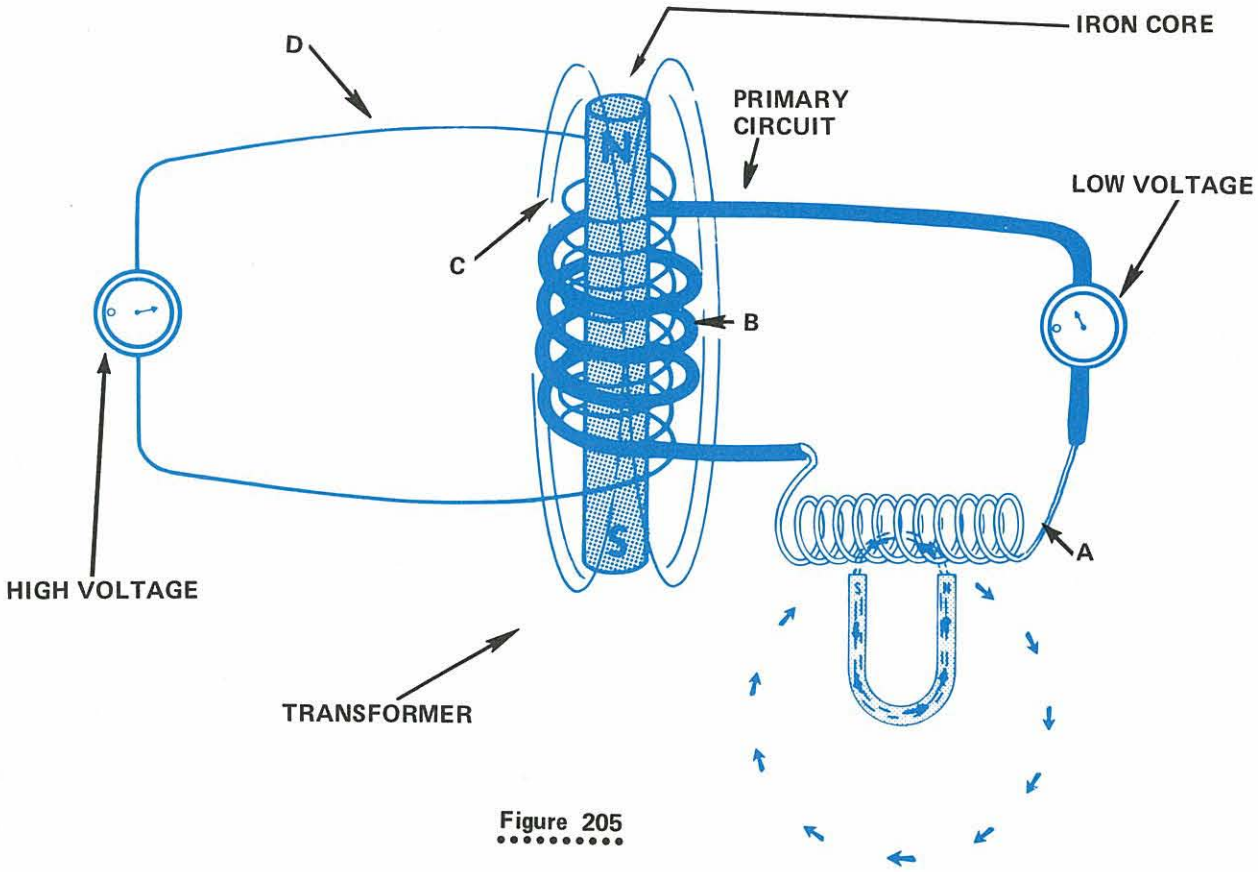


Figure 205

Figure 205 shows the basic principles of a magneto. The current producing or generator unit is shown at A. This supplies low voltage to the primary coil. This is accomplished by the magnet passing by the wire coil or the wire coil passing by the magnet which sets up an electric current. Low voltage current is fed to the primary coil of the transformer shown at B. It then goes through the secondary coil shown at C and produces high voltage at D. The secondary circuit provides the high voltage current necessary to ignite the spark plug.

FLYWHEEL MAGNETO

The principles of the generator and transformer apply to the flywheel magneto. A permanent magnet is mounted in the flywheel and rotates past the coil. Many small engines are made with the coil mounted inside the flywheel as shown in Figure 206. The coil, shown at A, is mounted inside the flywheel and is adjustable so the distance between the magnets and the coil laminations, shown at B, can be adjusted for distance. We'll go into the reasons for this adjustment later.

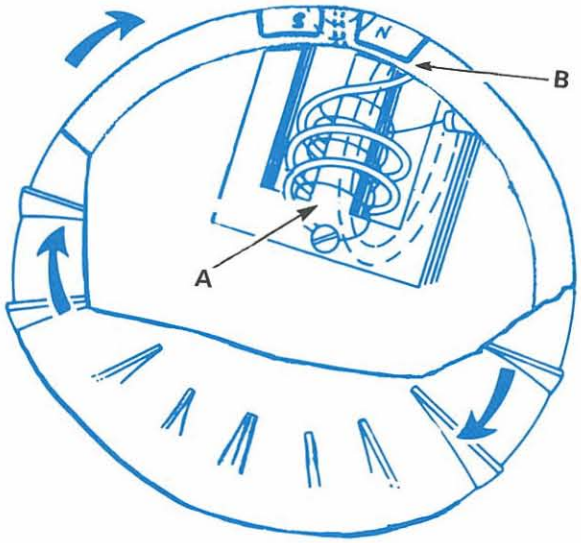


Figure 206

The coil can also be mounted on the outside of the flywheel with the magnets mounted on the inside. The following drawings will show the coil mounted on the outside. In the design of the magneto the generator coil also serves as the primary coil. Figure 207 shows an exploded view drawing of a magneto assembly. These parts will be common in almost all flywheel magnetos. Check these parts against the parts list so you will be familiar with their names and appearance.

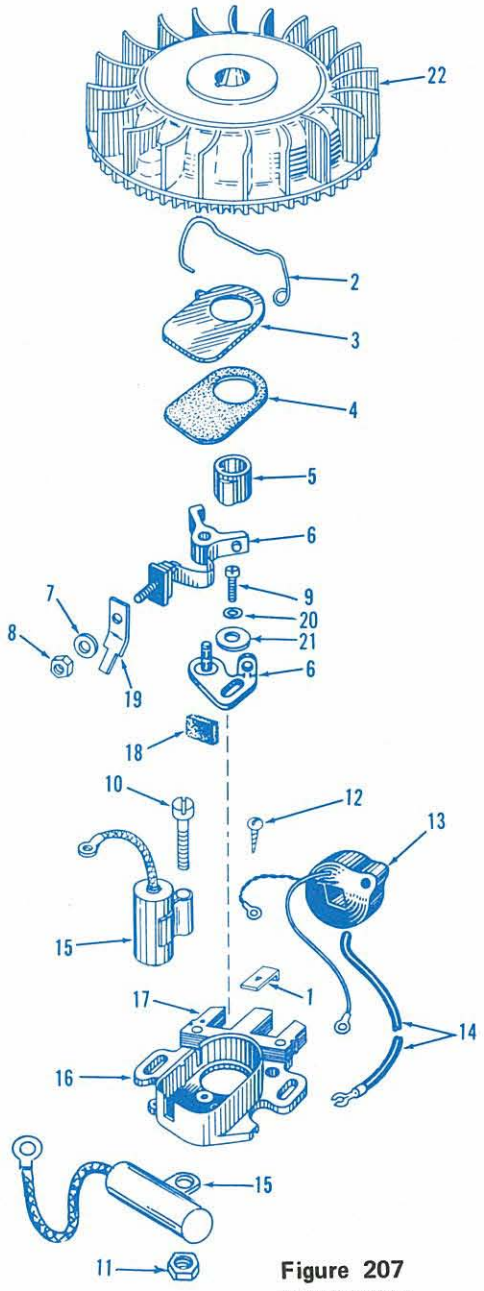


Figure 207

REF. NO.	PART NO.	PART NAME
1	27960	Clip, Core
2	27959	Spring, Breaker box cover
3	27957	Cover, Breaker box
4	27958	Gasket, Breaker box cover
5	27961	Cam, Breaker
6	27948	Contact Assy., Breaker
7	27955	Washer, Terminal
8	27988	Nut, Terminal
9	27952	Screw, Breaker
10	610593	Screw, Condenser
11	27954	Nut, Hex
12	27951	Screw, Ground terminal
13	27947	Coil Assy.
14	27950	Wire, Lead
15	27949	Condenser
16	27946	Core & Plate
17	27945	Stator Assy. (Incl. Nos. 1 & 6 thru 21)
18	27956	Felt, Cam wiper
19	29686	Tab, Ground terminal
20	27953	Lockwasher
21	24443	Flat washer
22	27944	Flywheel

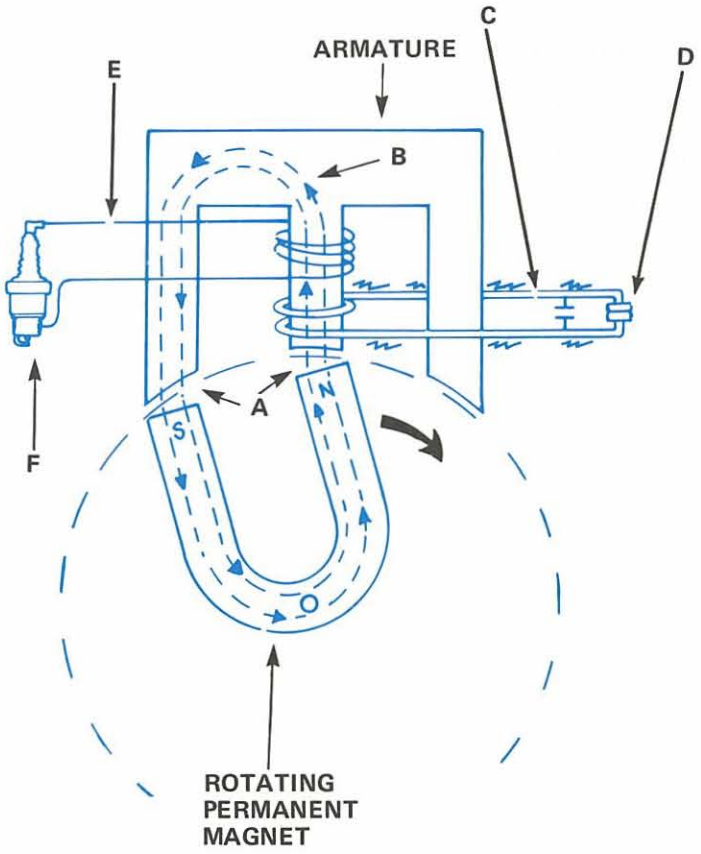


Figure 208

Instead of an iron core shown in these drawings as an example, a magneto uses a three-pronged soft iron core called a yoke or armature as shown in Figure 208. This armature is not one solid piece but usually is made of 10 or 12 thin pieces laminated together.

At the point where the north and the south pole of the magnet start to line up with the left-hand and center leg of the armature as shown at A, magnetic lines of force begin to flow through the center and left-hand legs of the armature as shown at B.

Voltage is induced in the primary coil and flows in the primary circuit shown at C. Notice the breaker points D are closed and make a complete circuit on the primary side. No current flows in the secondary circuit at E because the spark plug gap at F is open and the voltage is not enough to jump the gap.

As the magnet continues to rotate to a position where the north and south poles of the magnet are in the position shown in Figure 209, the lines of force start to flow in the center leg of the armature and both of the outside legs. When this happens the magnetic field is strongest at this point and the breaker points at A are timed to open at the instant the magnetic field reaches maximum strength. Later when we go into magneto timing we'll see how this happens.

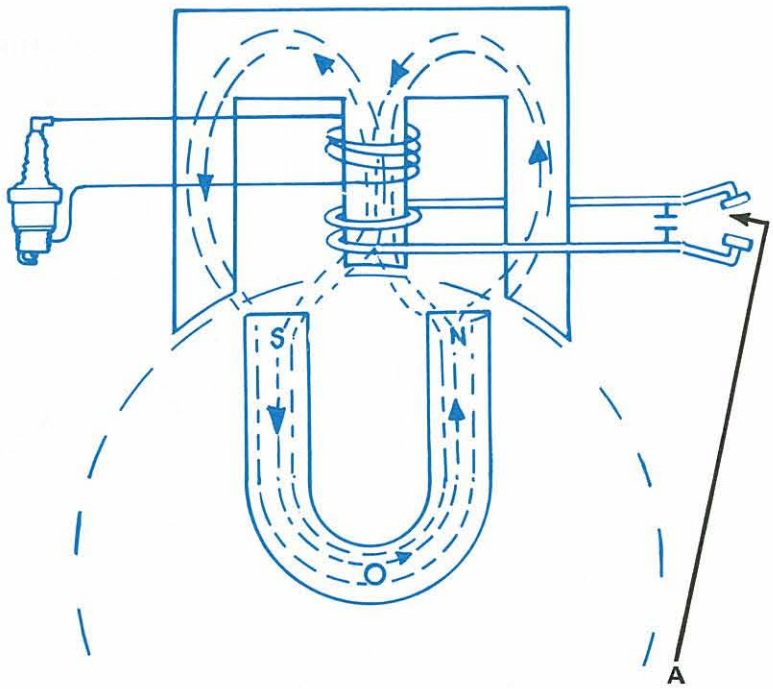


Figure 209

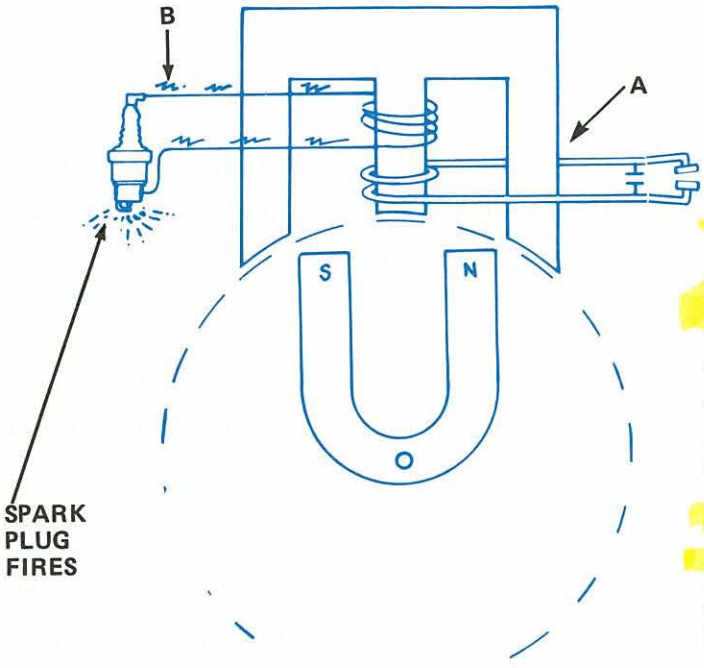


Figure 210

When the breaker points open the flow of current stops in the primary circuit, the strong magnetic field collapses. This sudden collapse of the primary circuit induces enough voltage in the secondary coil to cause the current to jump the gap at the spark plug as shown in Figure 210.

The reason current does not jump the gap at the breaker points is because of the low voltage. Going back to the transformer theory we actually have two transformers involved in the magneto. The one at the breaker points at A produces low voltage and the one going to the spark plug at B produces a high enough voltage to jump the spark plug gap.

STOPPING MAGNETO EQUIPPED ENGINES

The electrical system of an engine does not use as many wires for the electrical circuit as we have shown in these drawings since a circuit uses the engine frame as a common ground to complete the electrical circuit.

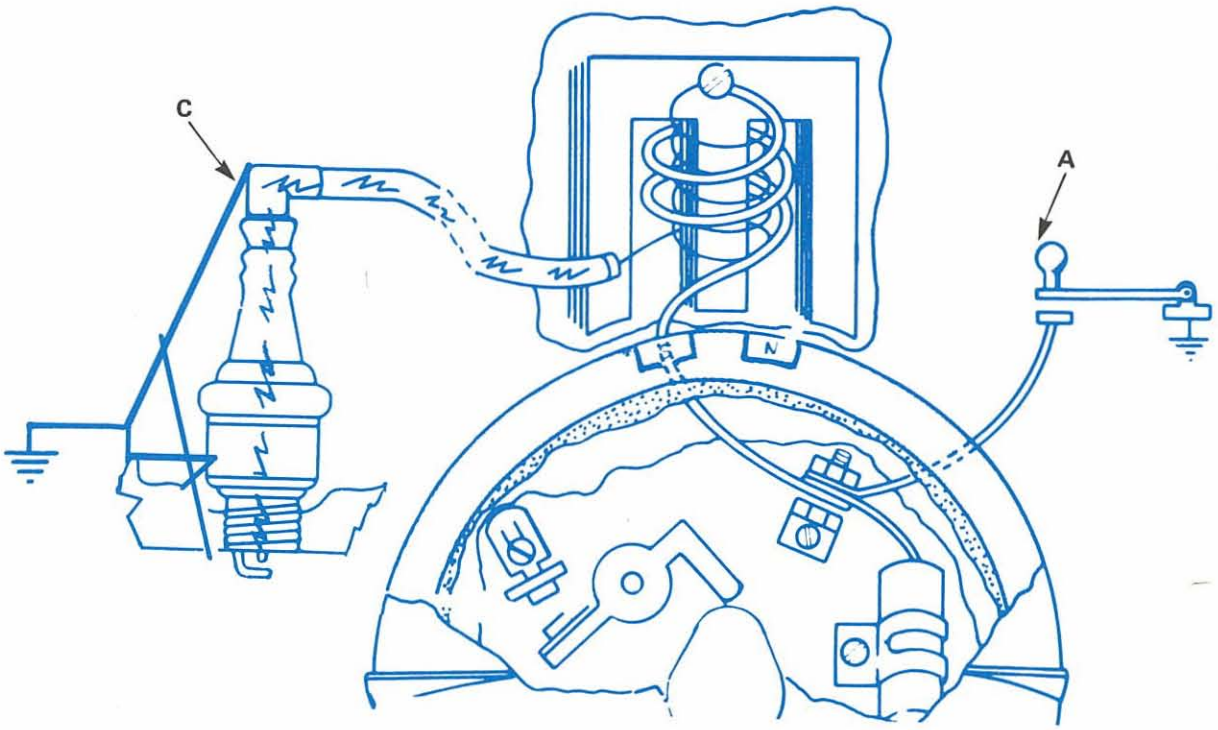
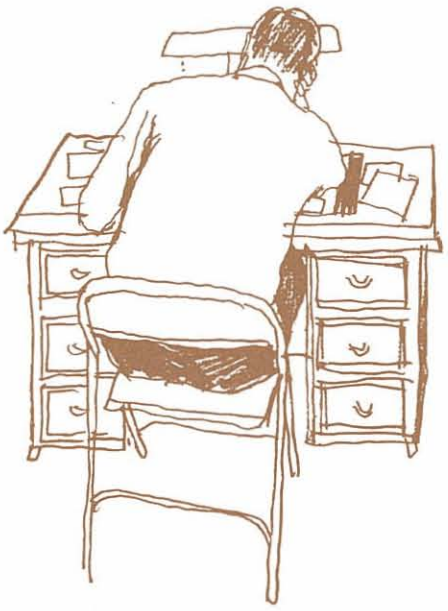


Figure 211

Figure 211 shows an ignition switch in the open position at A. This switch is attached to ground, or the engine frame, and the other side is connected to the primary side of the coil. When this switch is closed, or grounded to the engine frame, current will no longer flow through the primary coil since electricity will take the path of least resistance, which would be to the ground. With no current flowing to the primary circuit, there would be no current induced into the secondary circuit to fire the spark plug. The engine would stop. An engine switch is connected to this low voltage side of the coil.

Another method is to short out the spark plug. The outside part of the spark plug is attached to ground. If the plug is shorted across or grounded as shown at C, the plug will no longer fire since current will take the path of least resistance and go direct across the short instead of jumping the gap at the spark plug electrodes.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 22
MAGNETO PRINCIPLES

FOLEY-BELSAW INSTITUTE OF
SMALL ENGINE REPAIR
6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The breaker points are timed to _____ at the instant the magnetic field reaches its maximum strength. _____
   a. open
   b. close
   c. neither of the above

2. The magnetic ignition system produces its own electricity without the help of a generator or battery. _____
   TRUE
   FALSE

3. Voltage can be decreased or increased by running it through a _____. _____
   a. transformer
   b. battery
   c. magneto

4. Some engines are stopped by grounding the high voltage side of the coil at the spark plug. _____
   TRUE
   FALSE

5. The purpose of the ignition is to provide a spark of the proper voltage to the spark plug at the exact time. _____
   TRUE
   FALSE

6. When the breaker points open, the flow of current stops in the primary circuit. _____
   TRUE
   FALSE

7. The reason current does not jump the gap at the breaker points is because of the _____. _____
   a. high voltage
   b. low voltage
   c. ground

8. Transformers can be used to lower as well as raise voltage. _____
   TRUE
   FALSE

(Continued on page 2

9. The source of current for a magneto system is supplied from a _____. _____
   a. chemical action
   b. generator
   c. mechanical action

10. The secondary circuit of a transformer used in a magneto provides _____ voltage or current. _____
    a. high
    b. low
    c. constant

11. The engine switch is connected to the _____ voltage side of the coil. _____
    a. low
    b. high
    c. neither of the above

12. Magnetism creates imaginary lines of force. _____
    TRUE
    FALSE

13. Low voltage current is fed to the primary coil fo the transformer used in magnetos. _____
    TRUE
    FALSE

14. _____ ignition does not have a breaker point assembly. _____
    a. magneto
    b. generator
    c. solid state

15. The three basic types of ignition systems used on small engines are battery, magneto, and solid state. _____
    TRUE
    FALSE

16. A magneto uses a _____ type of magnet. _____
    a. transformer
    b. permanent
    c. electrical

17. The combination of a _____ and a _____ make up the basic components of a magneto. _____
    a. solid state, battery
    b. generator, transformer
    c. generator, solid state

LESSON NUMBER
23

...and let's find out all about --

ELECTRICAL DISTRIBUTION AND SOLID STATE IGNITION

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CONDENSER

A condenser might be compared to a shock absorber. Its primary purpose is to absorb excess current to keep the breaker points from arcing. Figure 212 shows the construction of a condenser. It consists of metal laminations or sheets as shown at A. These are separated by insulating paper shown at B. This paper and foil are wrapped around a metal disc or spool shown at C. The wire D comes from the coil and the coil is then grounded to complete the circuit.

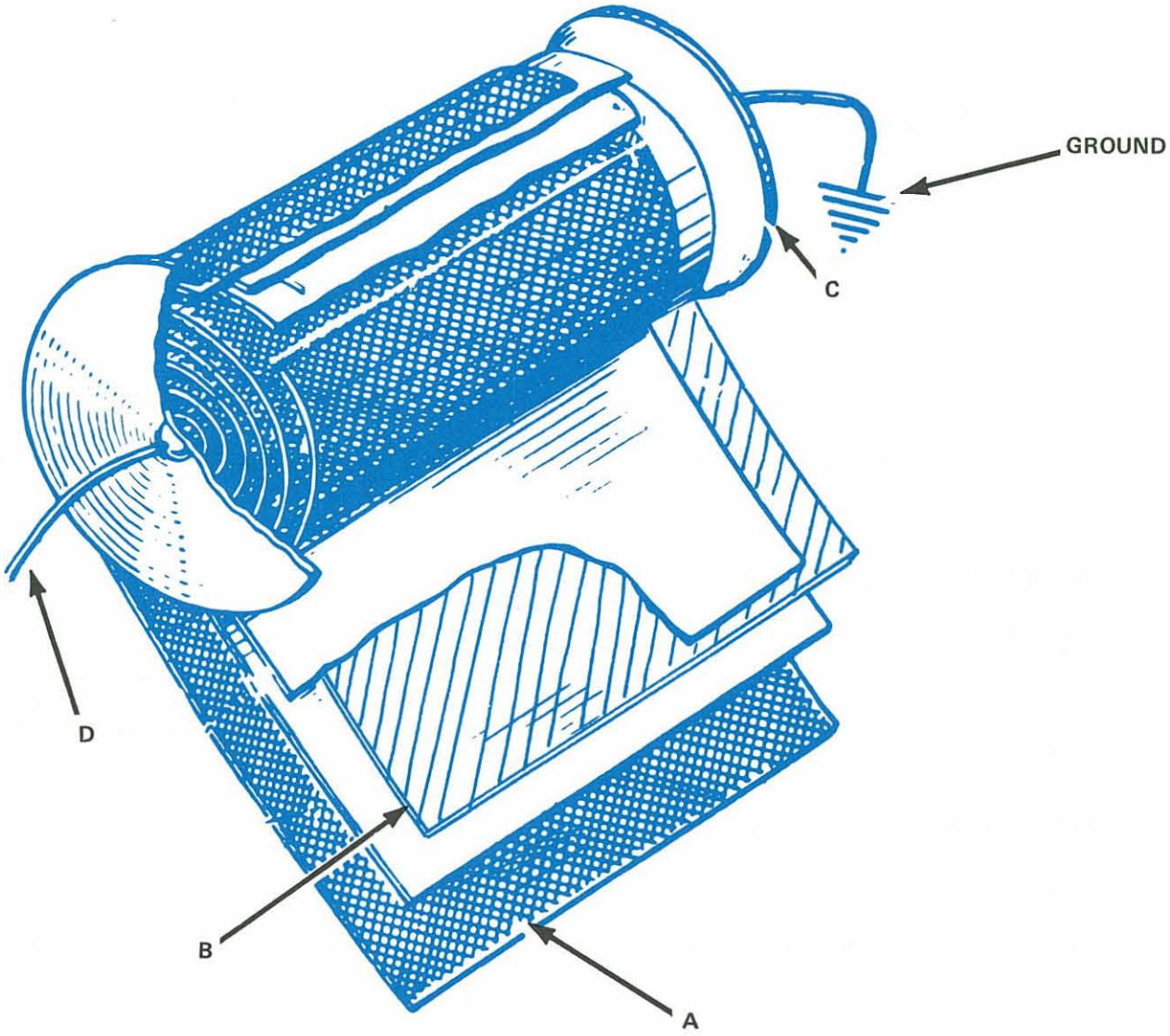


Figure 212

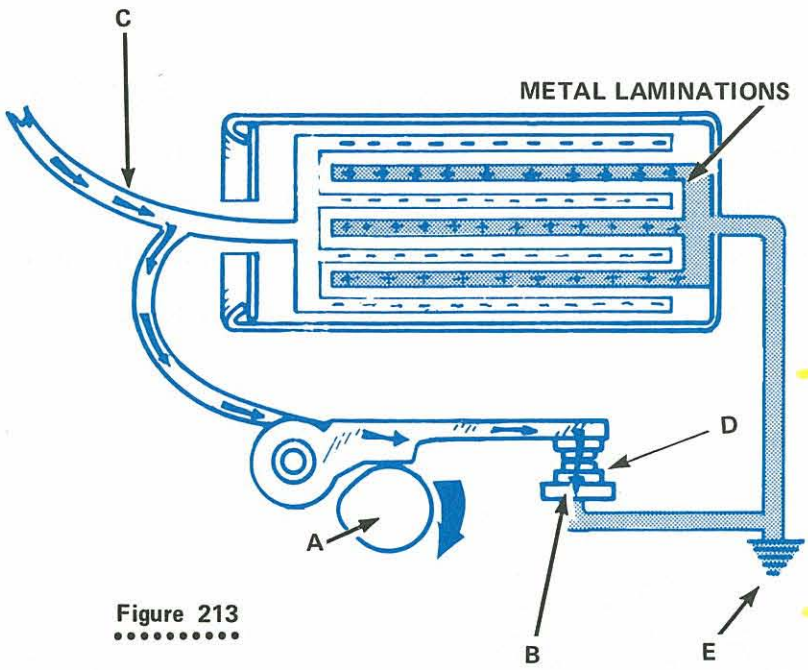


Figure 213

The condenser is out of service when the points are closed. Figure 213 shows what happens when the points close. The cam, shown at A, is timed with the engine to open and close the points at the proper time.

When the breaker points are closed, as shown at B, current from the coil comes in at C and goes direct to the contact points at D and then to ground at E. No current is flowing through the condenser at this time.

Figure 214 shows the contact points in the open position. Current cannot flow through the contact points so it has to go through the condenser to reach ground. With the points closed current will go through the points instead of the condenser because that is the path of least resistance.

Current flows through the condenser at A and direct to ground at B. The condenser absorbs most of the excess current that would otherwise go to the points. If excess current is allowed to reach the points it will cause arcing and burn or pit the points.

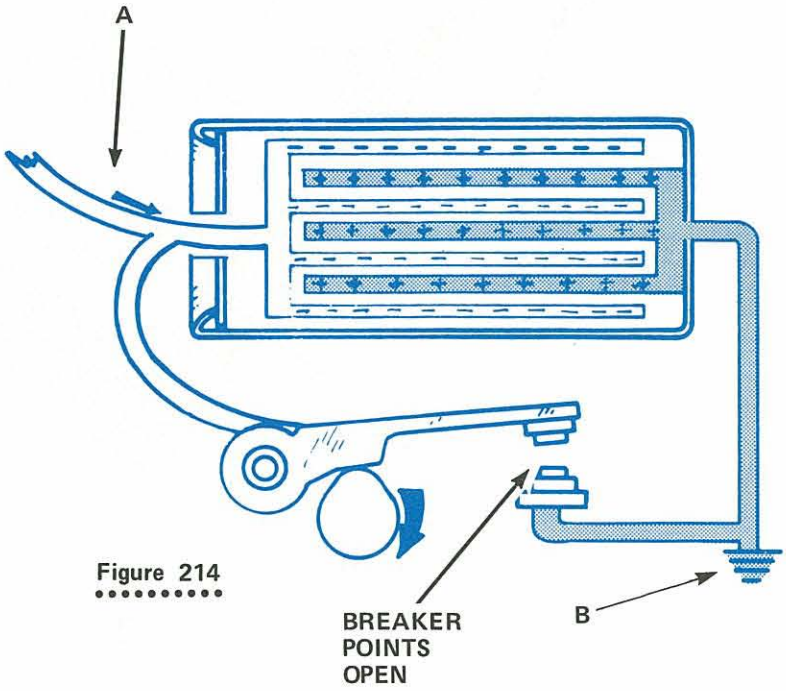


Figure 214

THREE STEPS OF THE MAGNETO

The first step of the magneto is shown in Figure 215. Magnetic lines of force A are built up around the coil B by the movement of the permanent magnet C past the armature D. The breaker points E are closed and the ignition switch F is open.

The second step is shown in Figure 216. As the magnet A passes the armature B the lines of force C are at the greatest strength and cause a high voltage to be induced into the secondary circuit going to the spark plug at D.

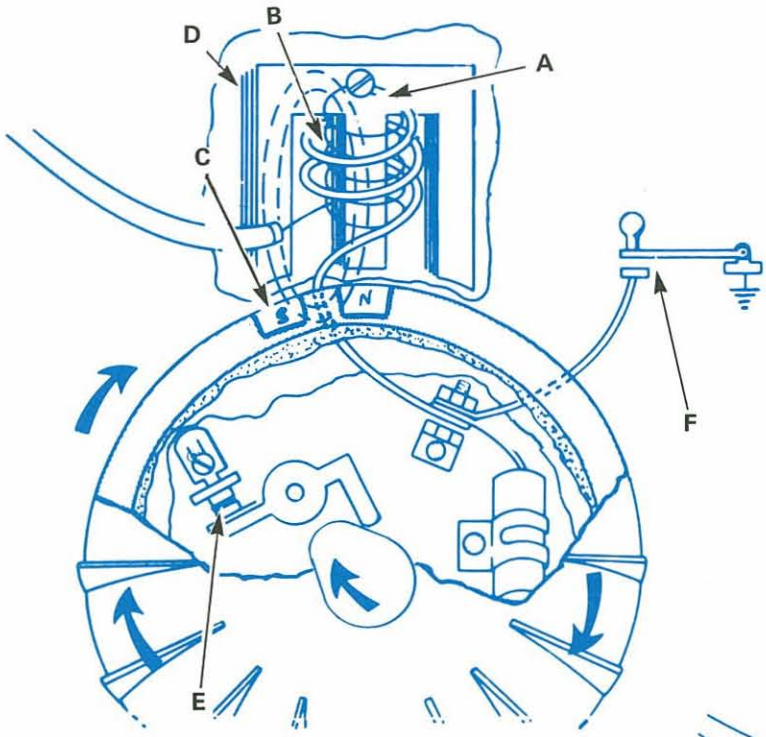


Figure 215

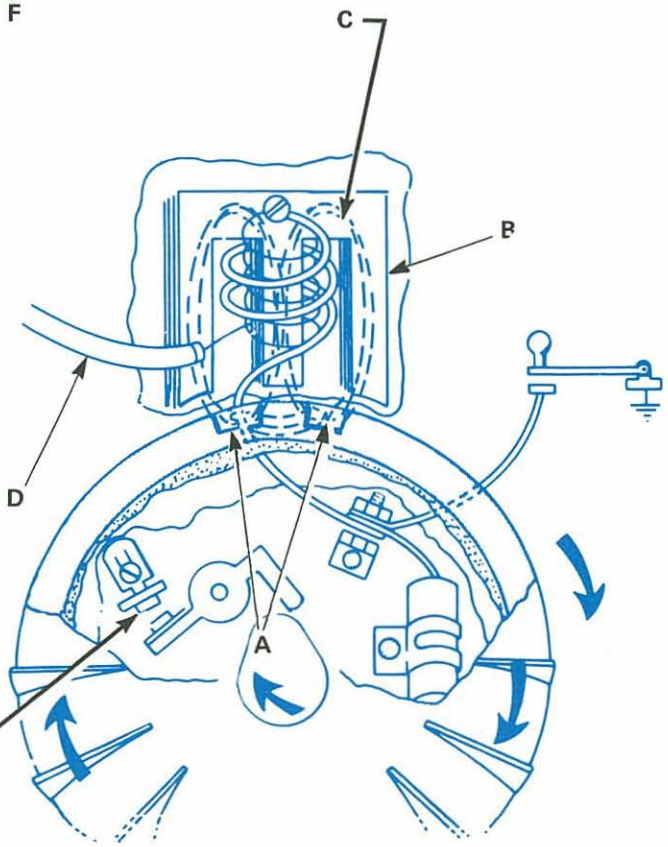


Figure 216

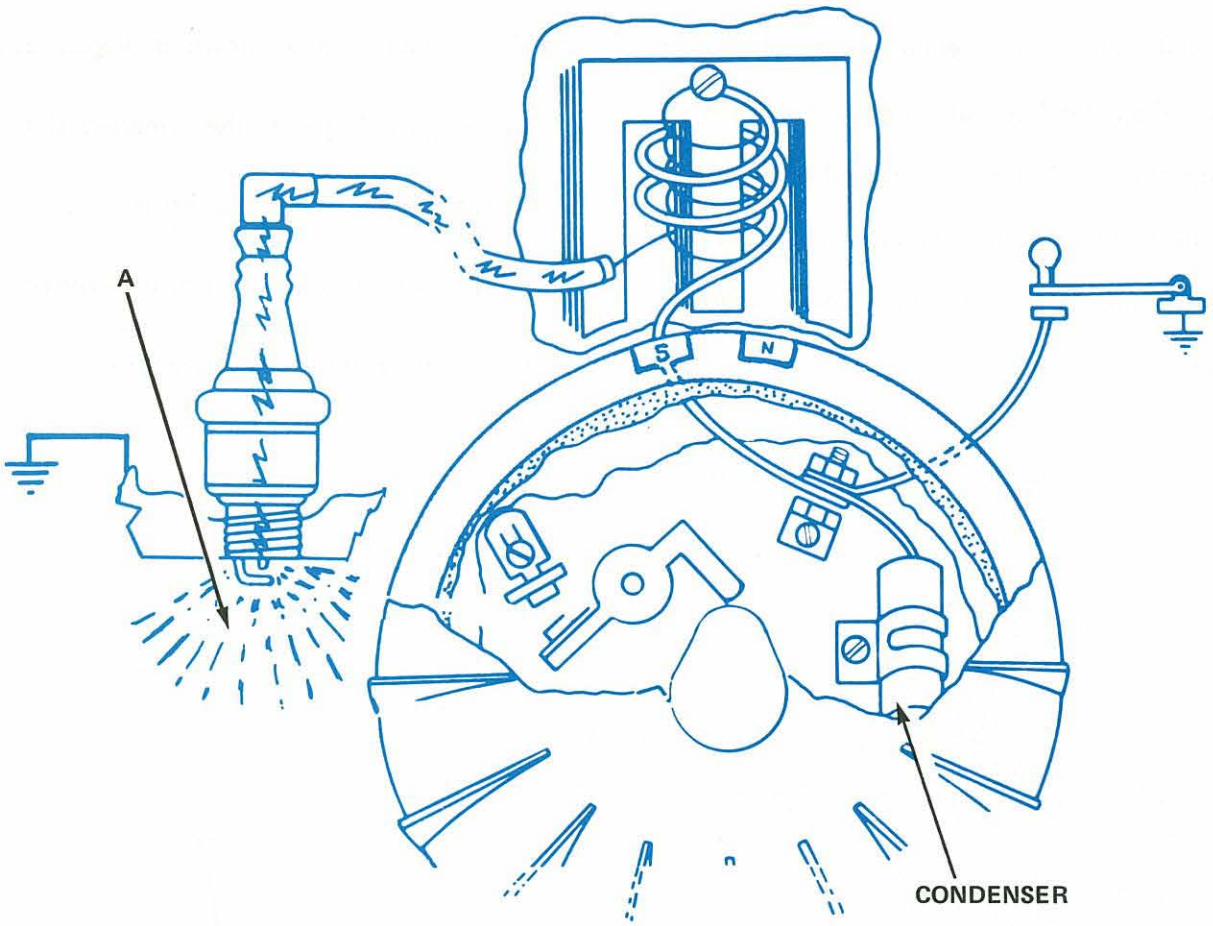


Figure 217

The third step is shown in Figure 217. The high voltage jumps the spark plug gap at A. This ignites the fuel-air mixture in the combustion chamber. The cycle then repeats itself.

DISTRIBUTOR

There is one part of the ignition system we haven't covered. So far we have been covering the ignition system in terms of a single cylinder engine. Engines with more than one cylinder operate on this same basic principle except they use a distributor to channel current to the proper spark plug at the proper time. A distributor is nothing more than a rotating switch that will make and break an electrical circuit at the proper time. Figure 218 shows the basic design of a distributor. This is for an engine having four cylinders. High voltage flows from the secondary at A to the center of the distributor shown at B. This is known as the rotor. From there it is connected by the switch and goes to the outside terminal at C. It then goes to the No. 2 spark plug and then to ground to complete the circuit when the plug fires.

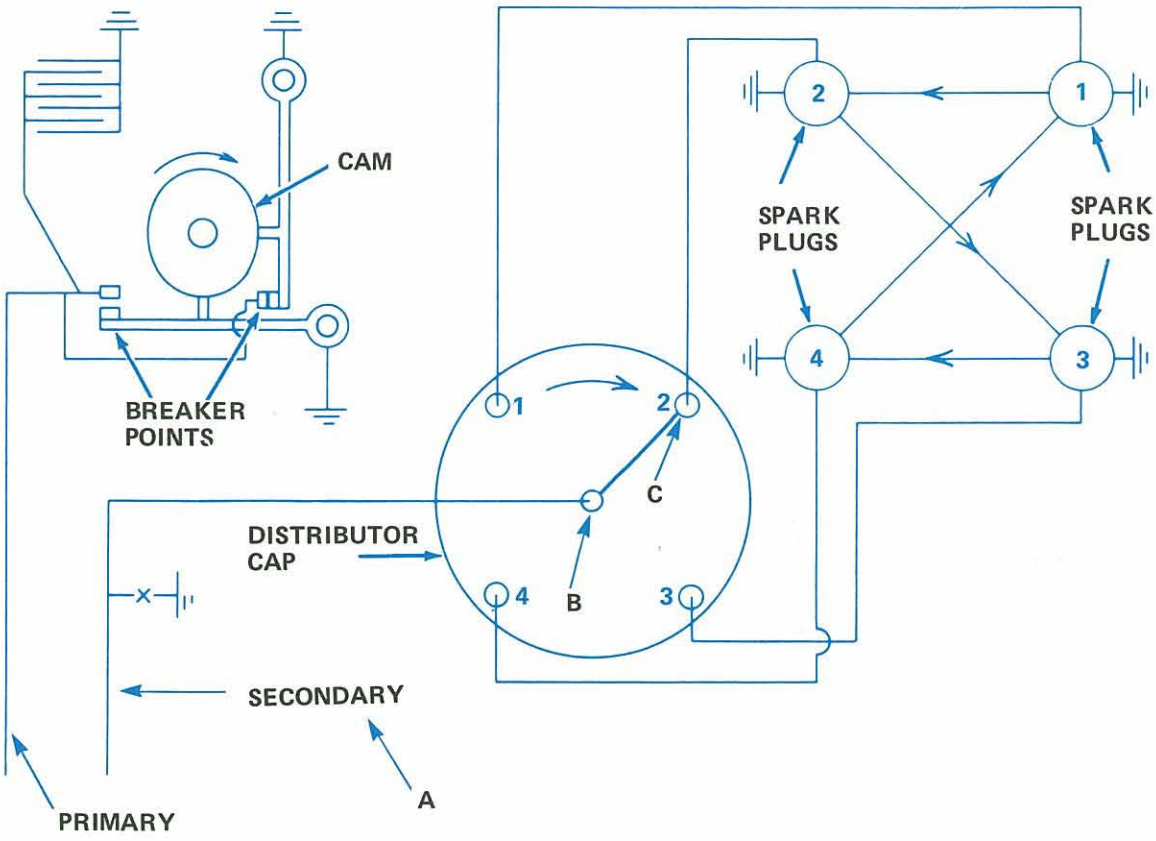


Figure 218

After the Number 2 spark plug has fired the rotor turns and makes contact with the Number 3 plug as shown at Figure 219. It then makes a complete circuit going to the spark plug and then to ground when the plug fires. The rotor continues to turn making this complete circuit with plugs Number 4 and Number 1 and then begins the cycle over again.

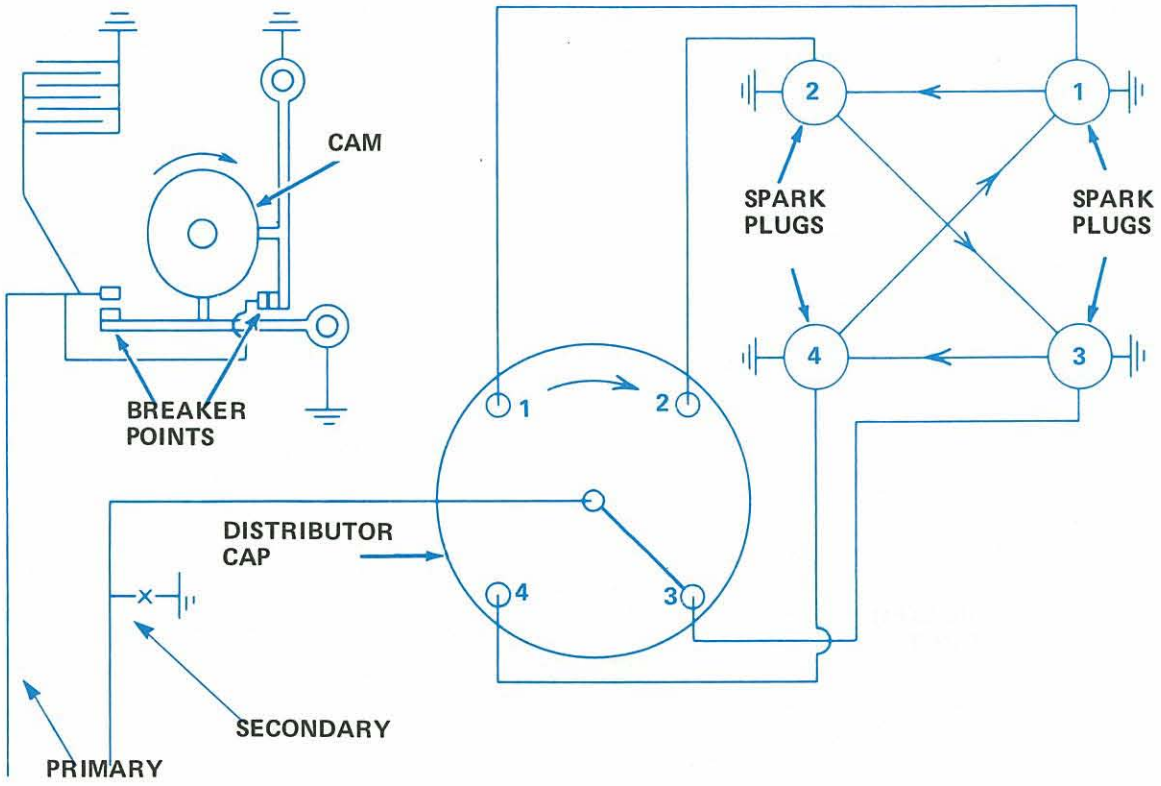


Figure 219

SOLID STATE IGNITION

Solid state ignition used on some small engines is very similar to the ignition system we have just covered except it does not use breaker points. Initial current is generated in a coil by a magnet on the flywheel. One basic difference other than the absence of breaker points is the solid state magneto generates alternating current while the conventional magneto generates direct current. The reason solid state starts with alternating current is to permit it to work with some of the electronic components that require alternating current. It is later converted to direct current before going to the spark plug.

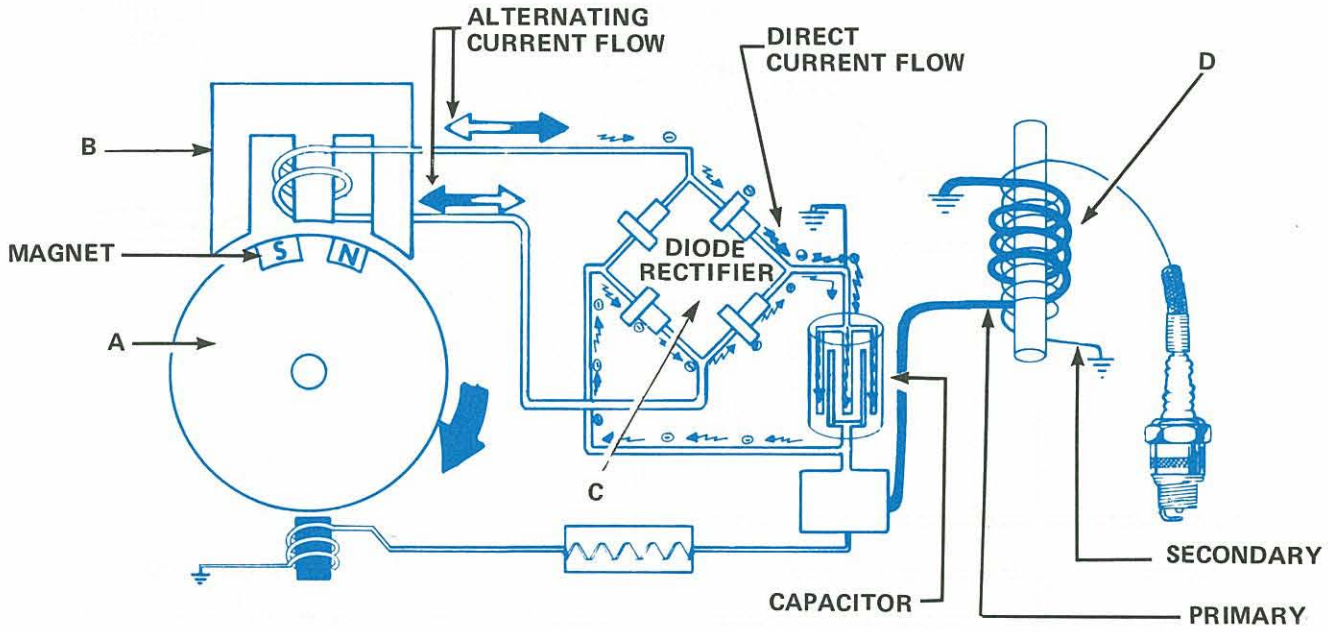
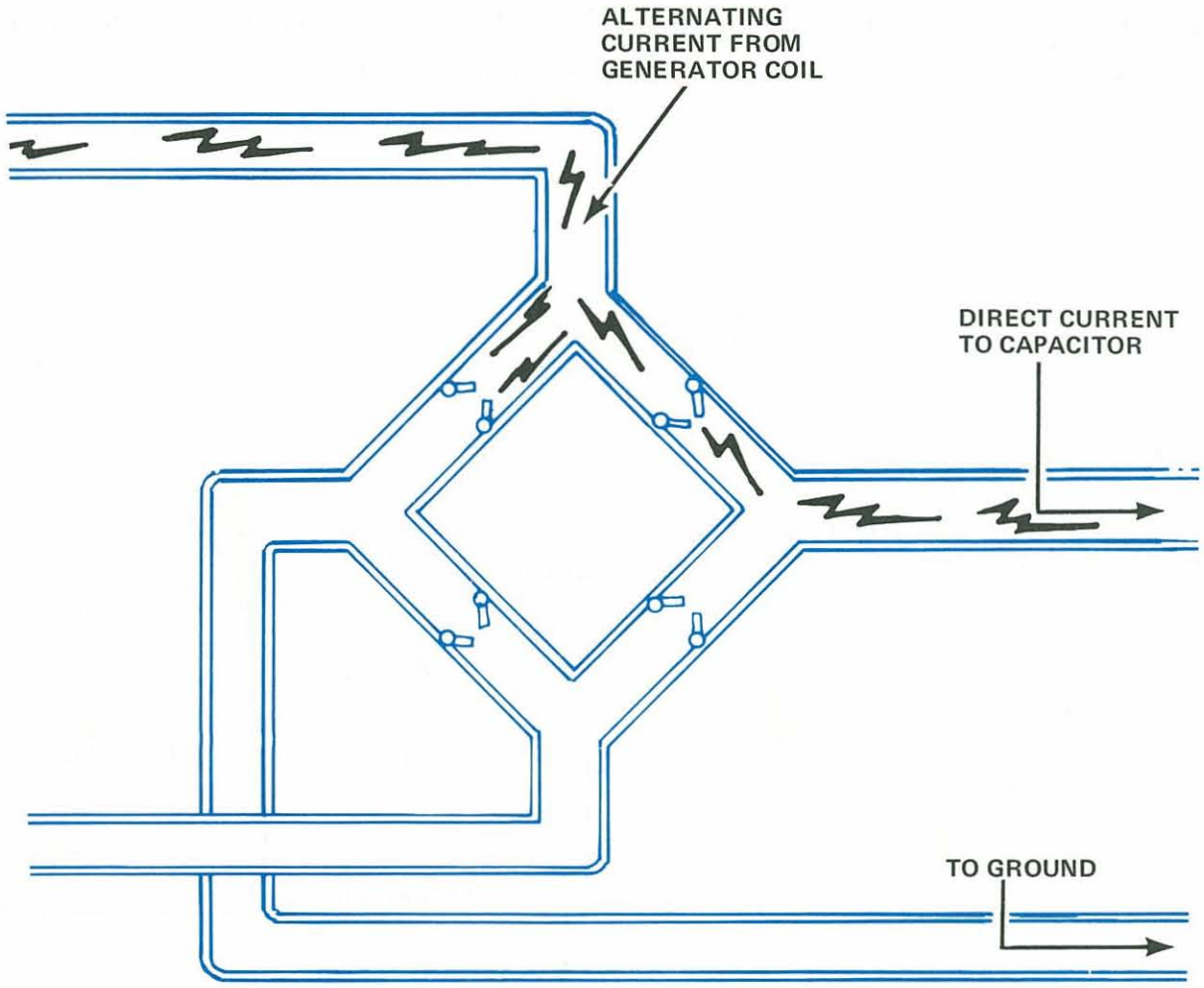


Figure 220

Figure 220 shows the components of a typical solid state ignition. The flywheel shown at A contains magnets that rotate past the coil and armature shown at B. This generating unit is designed to produce alternating current. The alternating current goes to the diode rectifier shown at C. It is then changed to direct current. The direct current then goes to the ignition coil, shown at D, where the D. C. voltage is stepped up high enough to jump the spark plug gap.

The diode rectifier between the generating unit and the ignition is all electronically controlled to fire the spark plug at the proper time. This is the unit that replaces the points and condenser assembly. This is a sealed unit, not repairable, and must be replaced as a unit.

To get a better idea how the diode rectifier operates look at Figure 221. It is an electrical device that will allow current to pass in one direction only. As we studied earlier, alternating current flows first in one direction, alternating back in the other direction. When A.C. is passed through the diode rectifier from the generating coil it is trapped at the diode rectifier and not allowed to reverse itself.



In Figure 221 we have the electrical current changed from A.C. to D.C. and going to the coil to be stepped up to a high enough voltage to ignite the spark plug.

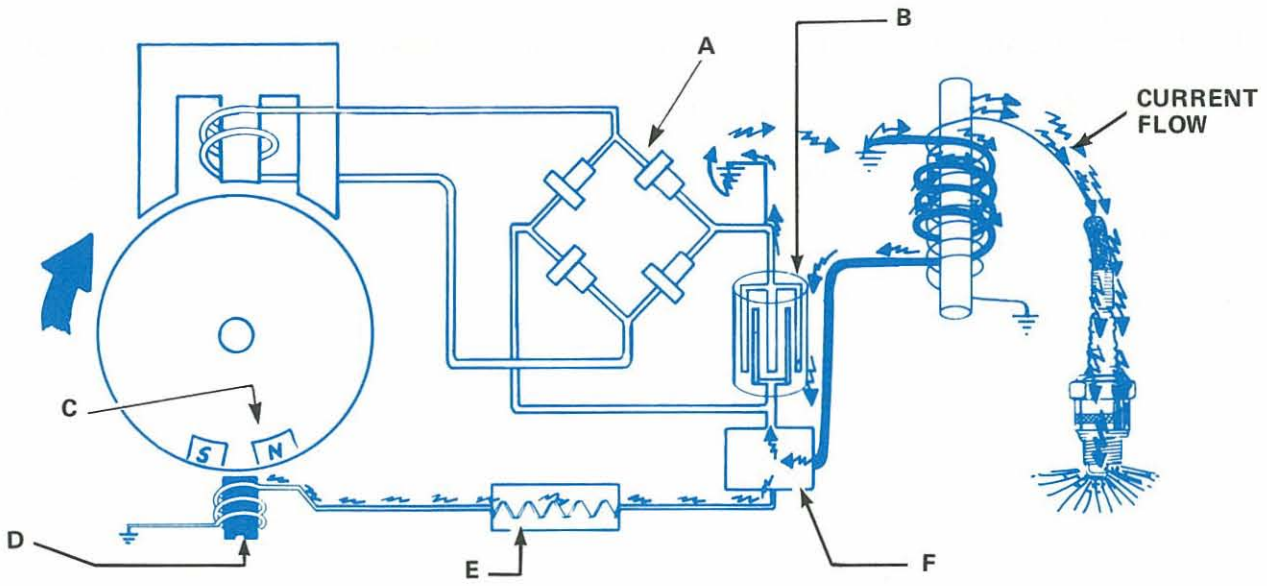


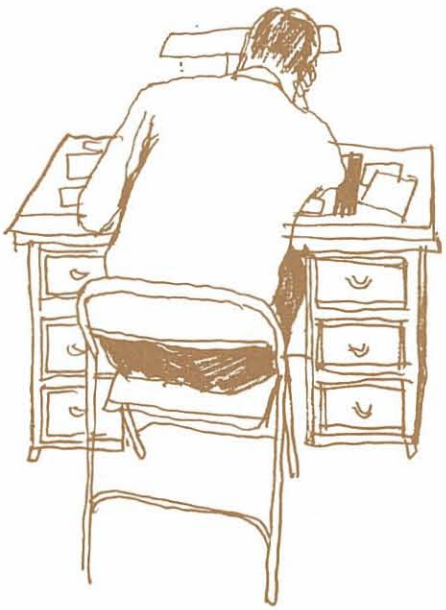
Figure 222

Figure 222 shows the condition after it has been changed to direct current. As direct current flows from the rectifier at A, it goes to a capacitor, shown at B, where it is stored momentarily. Current remains stored in the capacitor until the flywheel rotates one-half turn as shown at C. At this point the piston is at the proper place before top dead center and ready for the ignition spark to cause combustion.

As the magnet on the flywheel passes the trigger coil shown at D, a small amount of current is generated in the trigger coil. This current flows through the resistor, shown at E, and the transistorized switch shown at F. This current flow through the transistorized switch completes the circuit which allows the charge in the capacitor to escape. This allows current going to the coil to be increased to a high enough voltage to ignite the spark plug. This is called a capacitor-discharge type of solid state ignition. This is the type used on most small engines. There are other types but these are the basic principles of their operation.

TROUBLE SHOOTING SOLID STATE IGNITION

Trouble shooting solid state ignition is very limited. The high tension lead going to the spark plug should be inspected for cracks or indications of arcing. If there is no spark at the plug the trouble will almost always be in the solid state module itself and will need replacing. There could be trouble in the flywheel and magnet area and we will cover these checks later.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

(Fold Here)

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ADDRESS_____

CITY-STATE-ZIP_____

EXAMINATION ON LESSON 23
ELECTRICAL DISTRIBUTION AND SOLID STATE IGNITION

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NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The points will burn or pit if they receive excess current. _____
   TRUE
   FALSE

2. No current is flowing through the condenser when the contact points are closed. _____
   TRUE
   FALSE

3. The condenser absorbs most of the excess current that otherwise would go to the _____. _____
   a. points
   b. ground
   c. diode rectifier

4. The primary purpose of the condenser is to absorb excess current and to keep the breaker points from _____. _____
   a. arcing
   b. burning
   c. pitting
   d. all of the above

5. The _____ used in a solid state type ignition system will allow current to pass in one direction only. _____
   a. alternator
   b. diode rectifier
   c. points

6. The condenser is out of service when the points are _____. _____
   a. closed
   b. opened
   c. makes no difference

7. When the contact points are in the open position, current goes through the condenser to reach ground. _____
   TRUE
   FALSE

(Continued on page 2)

8. The solid state magneto generates direct current and converts it into alternating current. _____
   TRUE
   FALSE

9. When the breaker points are _____ current from the coil goes direct to the contact points. _____
   a. open
   b. closed
   c. makes no difference

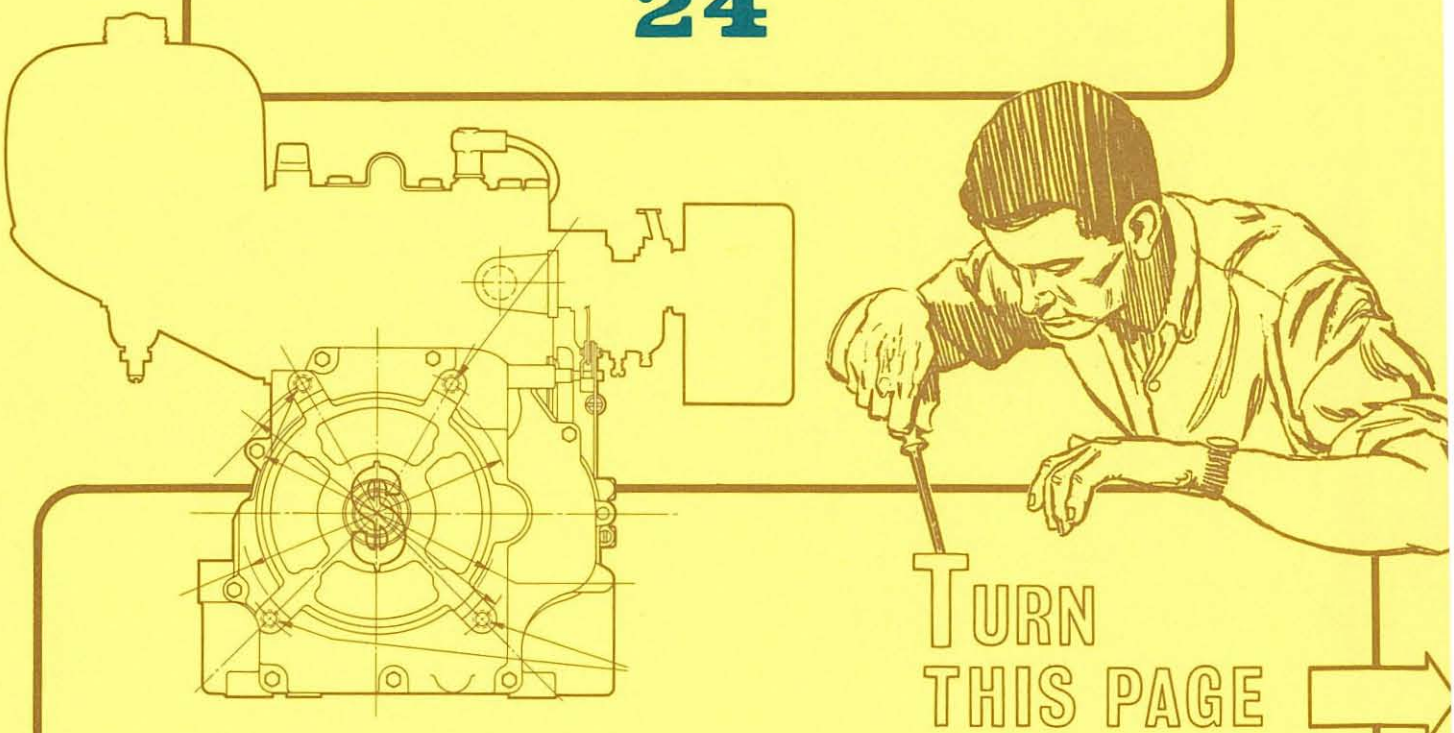
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

24



TURN THIS PAGE

...and let's find out all about -- **SPARK PLUGS**

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PARTS OF THE SPARK PLUGS

Before going into the maintenance and servicing of the conventional magneto electrical circuit it will be necessary to cover the fundamentals and principles of operation of the spark plug. Most of us are familiar with the spark plug and they would appear to be quite simple. They are a very important part of the electrical system, especially on a single cylinder engine. A properly maintained plug can mean as much as 50 percent of the efficiency of the engine. It could mean hard starting, poor engine performance and actual damage to the engine combustion chamber.

The spark plug provides the means whereby a spark can occur inside the combustion chamber of the engine. The electric current from the magneto or the ignition coil travels at regular intervals through the high tension wire to the spark plug terminal. Figure 223 shows the different parts of a typical spark plug. The high tension wire is shown at A. This is the wire carrying voltage from the magneto or coil and will reach 10,000 to 20,000 volts. The center electrode is at B and carries voltage from the high tension wire to the spark plug gap. It is very important that the gap shown at C, between these electrodes be set at the proper distance apart for an efficient operating plug. This space should be .025 to .030 on most small engines.

The high voltage then jumps the gap to the ground electrode at D causing a spark that is timed to ignite the fuel and air mixture at the proper time it is under compression. There is a copper gasket or other soft material at E that makes a seal between the spark plug and the engine housing. The ground electrode D is insulated from the center electrode B by the insulator shown at F.

A fouled spark plug is a very common problem with small engines. This is caused when carbon deposits form between the center electrode and the ground electrode. This prevents the spark from arcing across and causing the spark necessary to ignite the fuel-air mixture.

SPARK PLUG

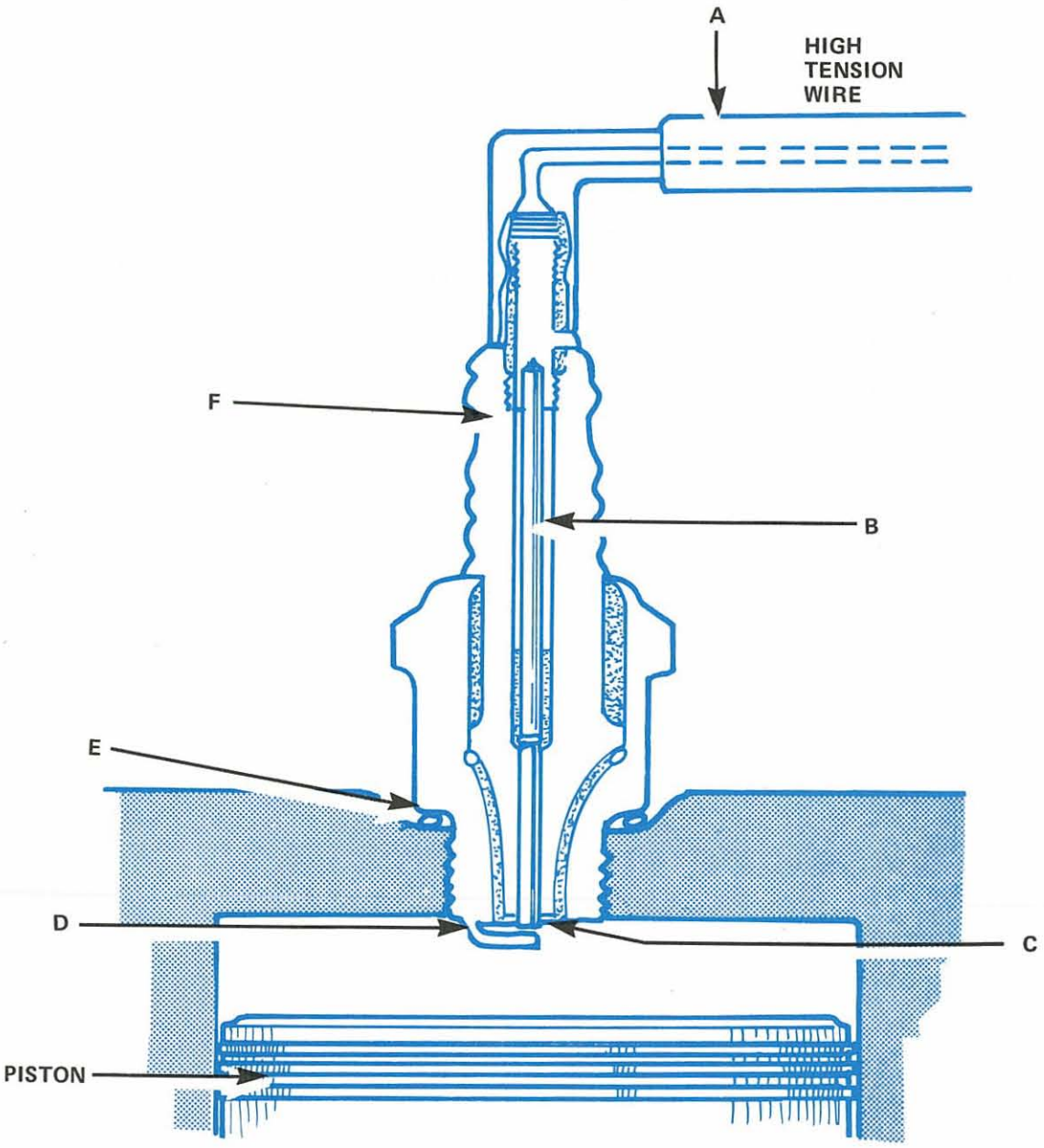


Figure 223

TYPES OF SPARK PLUGS

Spark plugs, in general, appear to be very much the same in appearance and function. Here the similarity ends. Spark plugs are quite different even though they may appear to be the same. Engine design and application are taken into consideration in choosing the proper spark plug for the engine.

Spark plugs are made by a number of different equipment manufacturers. The most common are Champion, Autolite and A. C. plugs. Each manufacturer uses their own part or brand number, however, there are tables showing their interchangeability. Figure 224, on page 4, shows a typical cross reference chart. The Champion plug N-8 is interchangeable with the Autolite plug AGZ7. It is also interchangeable with the Bosch W145T2. These plugs are interchangeable and have the same general quality. They may not have exactly the same characteristics but they will be similar enough to be interchangeable.

These cross reference catalogs are available from most all automotive supply houses. When you consider that three major manufacturers make over 90 per cent of the small engines used on lawnmowers, snowblowers, chain saws and other similar applications, the spark plug inventory for the repairman is rather limited. There are about six different plugs used on the majority of these engines. As you get into repair work, you will be using factory catalogs which give specifications on spark plugs and other replacement parts.

Spark plugs are basically designed for engine operating conditions, kind of fuel used and engine design. These three conditions are the basis of the engineering selection for the spark plug. Operating conditions may vary from light loads to heavy continuous loads where the engine stays hot continuously.

To meet these changing conditions spark plugs are designed for three conditions, normal, cold and hot. The difference in the three types is the length of the insulator tip.

SAMPLE SPARK PLUG
CROSS REFERENCE CHART

AUTOLITE TO CHAMPION

AKO.....J-19V/UJ-17V	AE4.....L-86	AGZ7.....N-8
AGKO.....N-19V	AE4M.....L-86	A7X.....J-8J
AEKO.....L-19V/L-20V	AER4.....XL-85	AL7.....H-11
AF1.....BL-3	AG4.....N-6	AL7Y.....H-10J
AT1.....J-2J	AG4M.....N-6	AL7X.....H-10J
BTF1.....F-82	AT4.....J-7	ARL8.....XH-11

AC TO CHAMPION

M8.....UY-6	R42S.....RJ-10Y	MC44.....J-6J
14.....K-97F	R42T.....RBL-8	MR44C.....XJ-6J
16.....K-97F	R42TS.....RBL-11Y	R44.....XJ-7
16L.....K-98F	R42XLS.....RN-10Y	R44FF.....RL-12Y
17.....W-95D	S42.....J-4J	R44NS.....RN-12Y

BOSCH TO CHAMPION

M35T1.....D-21	MGV260T31S.....K-7	W145T1.....L-88A
M45T1.....D-21	M280T31.....K-5G	W145T2.....N-8
M95T1.....D-16	MG300T31.....K-3G	W145T3.....J-7
M95T5.....D-18Y		W145T6.....J-12Y
MA95T1.....870		W145T30.....N-12Y

KLG TO CHAMPION

F20.....L-14	FA70.....H-8	FE100.....N-3
F50.....L-90		FE125P.....N-6Y
F55P.....L-95Y	FE20.....N-21	
F65P.....L-87Y	FE30.....N-18	FS20.....UJ-12
F70.....L-10	FE45P.....N-14Y	FS30.....J-11

LODGE TO CHAMPION

2H.....L-10	BAN.....UJ-12	C14.....L-10
2HA.....J-8	BANY.....J-14Y	CAN.....J-8
2HAN.....J-4J	BBANY.....J-18Y	CANY.....J-12Y
2HL.....N-4	BBL.....D-16	CC14.....L-90
		CL10.....Z-10

NGK TO CHAMPION

A4F.....860	B6EW.....N-10Y	B8HC.....L-78
	B6H.....L-86	B8HN.....L-62R
A6.....D-14, K-13	B6HV.....L-6G	B8HZ.....L-81
A6F.....860	B6HS.....L-86	B8N.....J-62R
	B6L.....H-8	

Figure 224

HOT PLUGS

Figure 225 shows a typical hot plug. The length of the insulator nose, shown at A, determines how readily heat will pass from the spark plug to the cooling fins at B. The longer the insulator tip, the further heat must travel through the plug before it begins to be absorbed by the engine cooling fins.

A hot plug is needed for engines that do not reach extremely high operating temperatures. The term hot and cold, when used in reference to spark plugs, does not have anything to do with the intensity of the spark. The term is used to indicate the operating temperature of the plug.

HOT PLUG

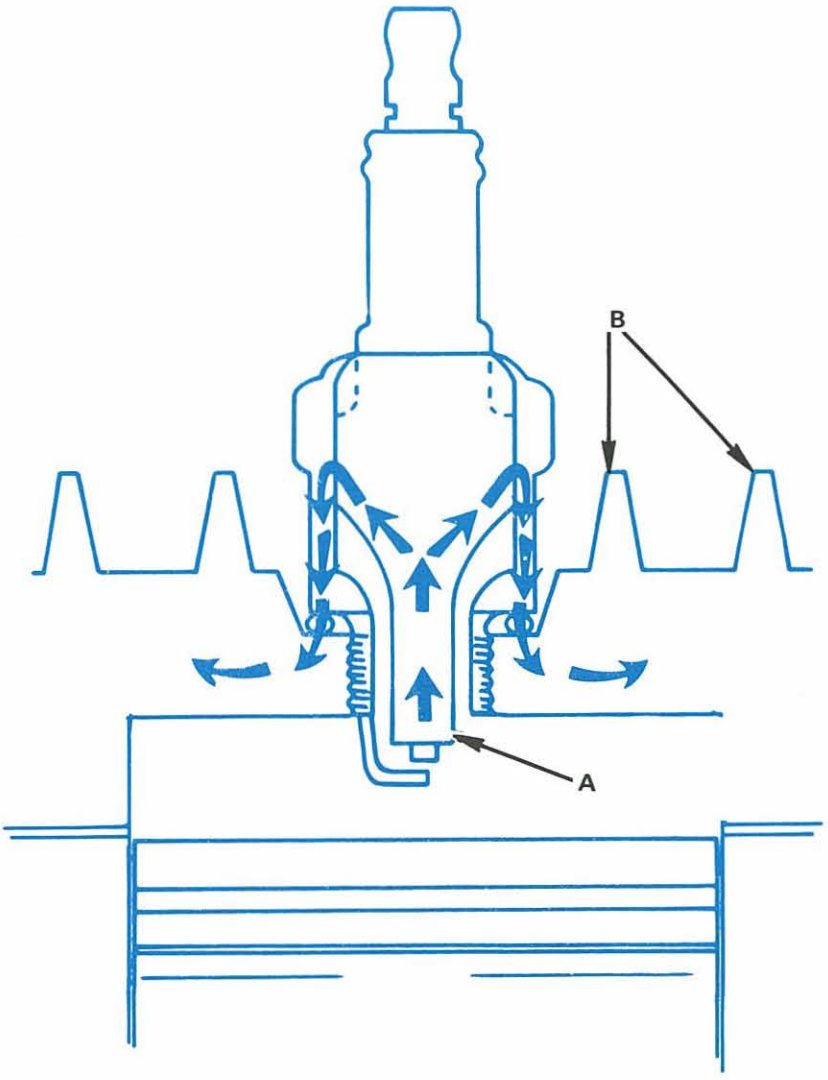


Figure 225

COLD PLUGS

Figure 226 shows a cold plug. Notice the distance shown at A is shorter when compared to the plug shown at Figure 225. This permits heat to be conducted to the cooling fins faster and makes the plug operate at a lower temperature. By using the proper heat spark plug you get longer plug life and more trouble-free service from the engine. The mixture of fuel and air causes carbon to be deposited on the electrodes of the plug which tend to foul the plug. The proper plug for the engine will become hot enough to burn itself free of much of this carbon deposit. At the same time it will not become hot enough to overheat and burn the electrodes. When plugs overheat they tend to burn the electrodes. When this happens the gap between the electrodes is increased.

COLD PLUG

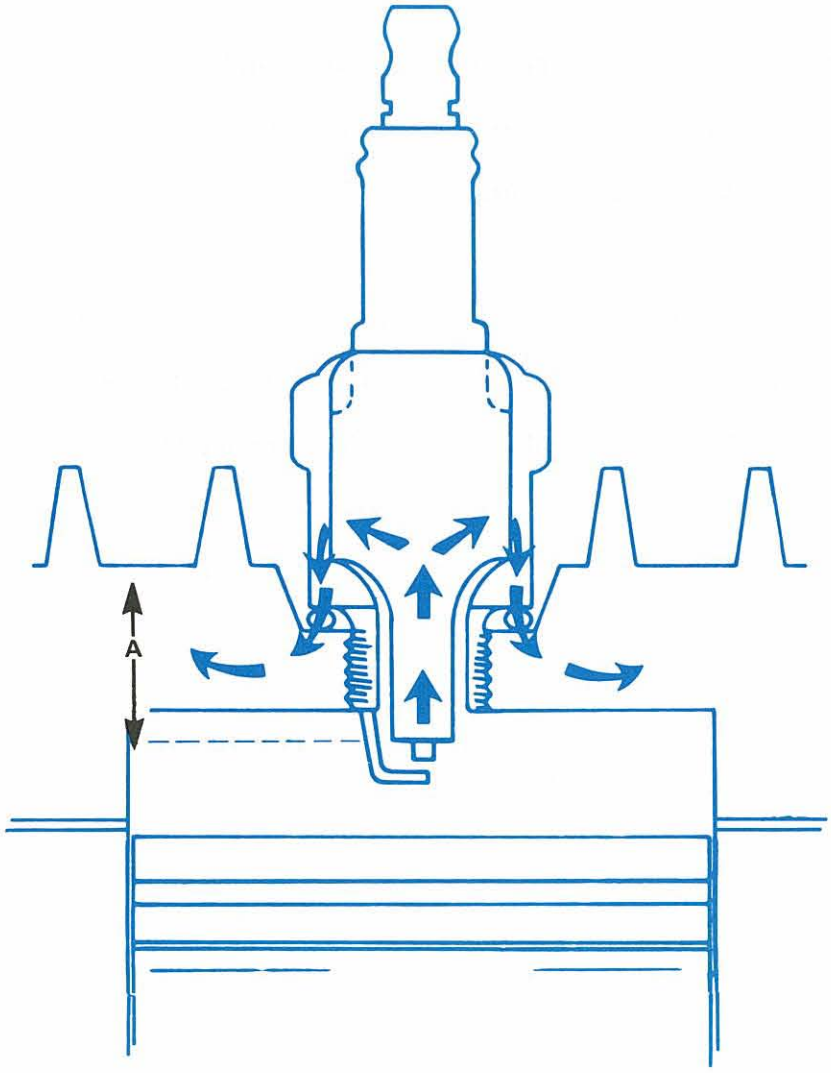


Figure 226

TYPICAL SPARK-PLUG REACHES

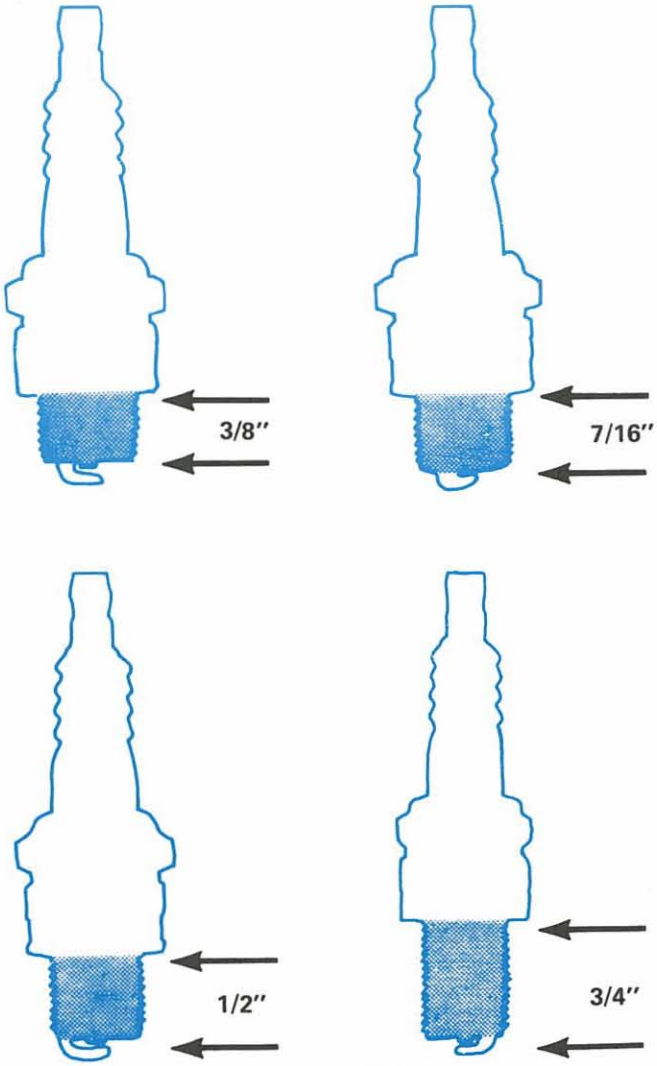


Figure 227

PLUG LENGTH

Plug length, sometimes called the reach, is determined by the engine design. The reach must be the proper distance to fit the different depths of engine heads so that the base of the plug will be even with the inside of the combustion chamber. Figure 227 shows the four reaches most common for small engines. These are designed to fit the different depths of engine heads. When replacing plugs it is good to check this distance with the one removed from the engine. They may not always be the same. Most small engines use either a 3/8-inch or 7/16-inch plug.

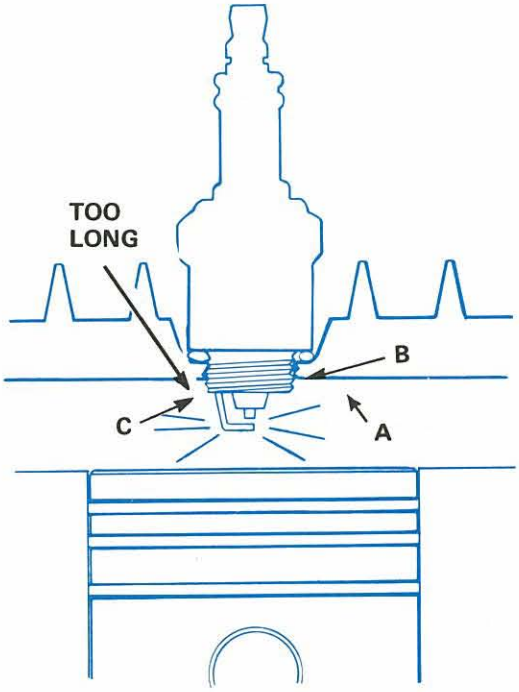


Figure 228

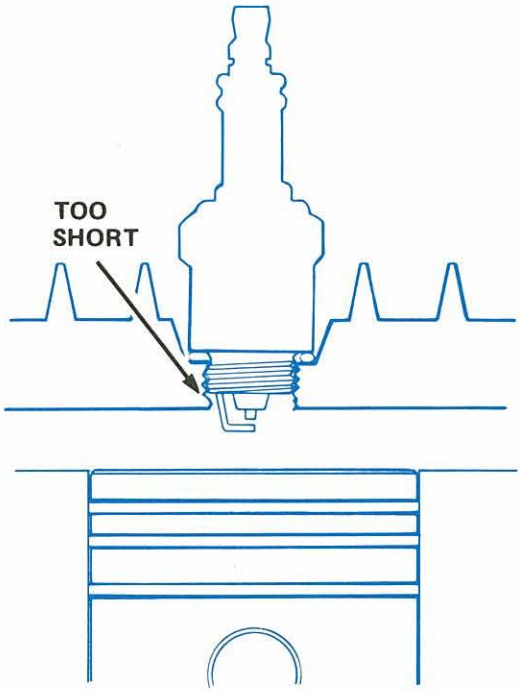


Figure 229

Figure 228 shows what would happen if the plug reach is too long for the particular engine. This plug extends too far down through the cylinder head as shown at A. The top of the piston can actually hit the plug. The thickness of the metal in the cylinder head, shown at B, requires a shorter plug reach. The long reach of this plug will not only interfere with the action of the piston but on some engines could interfere with the valve action. The threads of the plug will also collect carbon deposits at C and make it hard to remove. A plug with too little reach, as shown at Figure 229, will cause ignition to be too far above the top of the cylinder head. This results in poor fuel combustion.

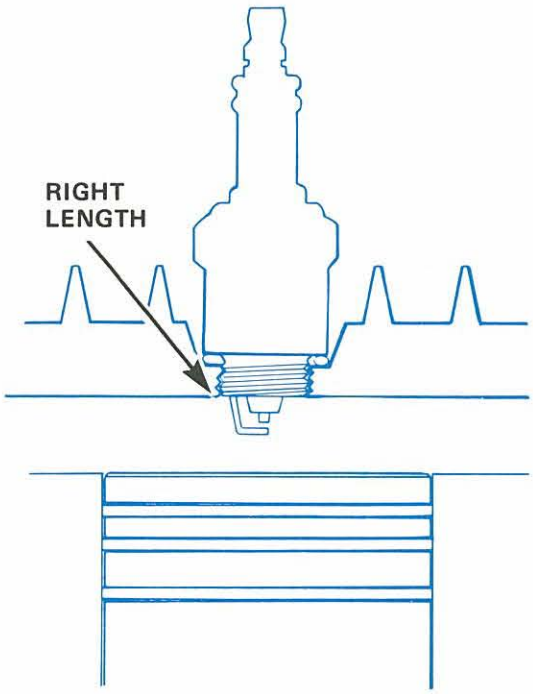


Figure 230

The proper plug reach should look like the one in Figure 230. The bottom of the threads come just to the inside edge of the cylinder head. This leaves no threads exposed inside the head, as shown in Figure 229, or outside, as shown in Figure 228.

PLUG THREAD AND REACH

Spark plug sizes use two measurements called thread and reach. Reach is the length as we have just covered. Figure 231 shows these two dimensions. The reach, shown at A, is the length of the threads and is generally expressed in fractions or decimals, such as 3/8-inch or .375 inch, which is the decimal equivalent. The thread, or diameter of the thread shown at B, is expressed in millimeters or "mm". It will generally run from 10 mm to 18 mm for most small engines.

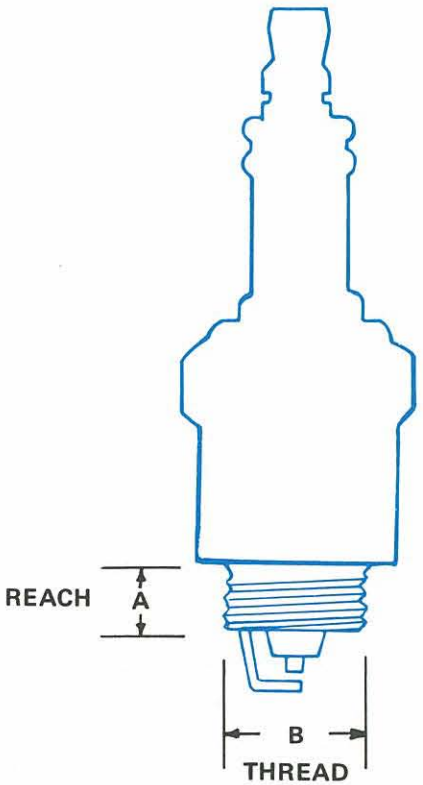


Figure 231

SPARK PLUG INSPECTION AND SERVICE

Most manufacturers recommend inspection and service of spark plugs every 100 hours of operation. For most lawnmowers, snowblowers and other similar applications this would generally need to be done more frequently than once a year. However, they should always be checked at least once a year.

You can check the condition of the spark plug by the intensity of the electrical discharge being supplied to the plug by the magneto or coil from battery ignition systems. First remove the spark plug lead wire shown in Figure 232. Pull straight up on the metal connector shown at A. Do not pull sideways or pull on the high tension wire. You could cause a bad connection between the metal connector and wire by pulling on the wire.

REMOVING SPARK-PLUG LEAD

Figure 232

REMOVING SPARK PLUG

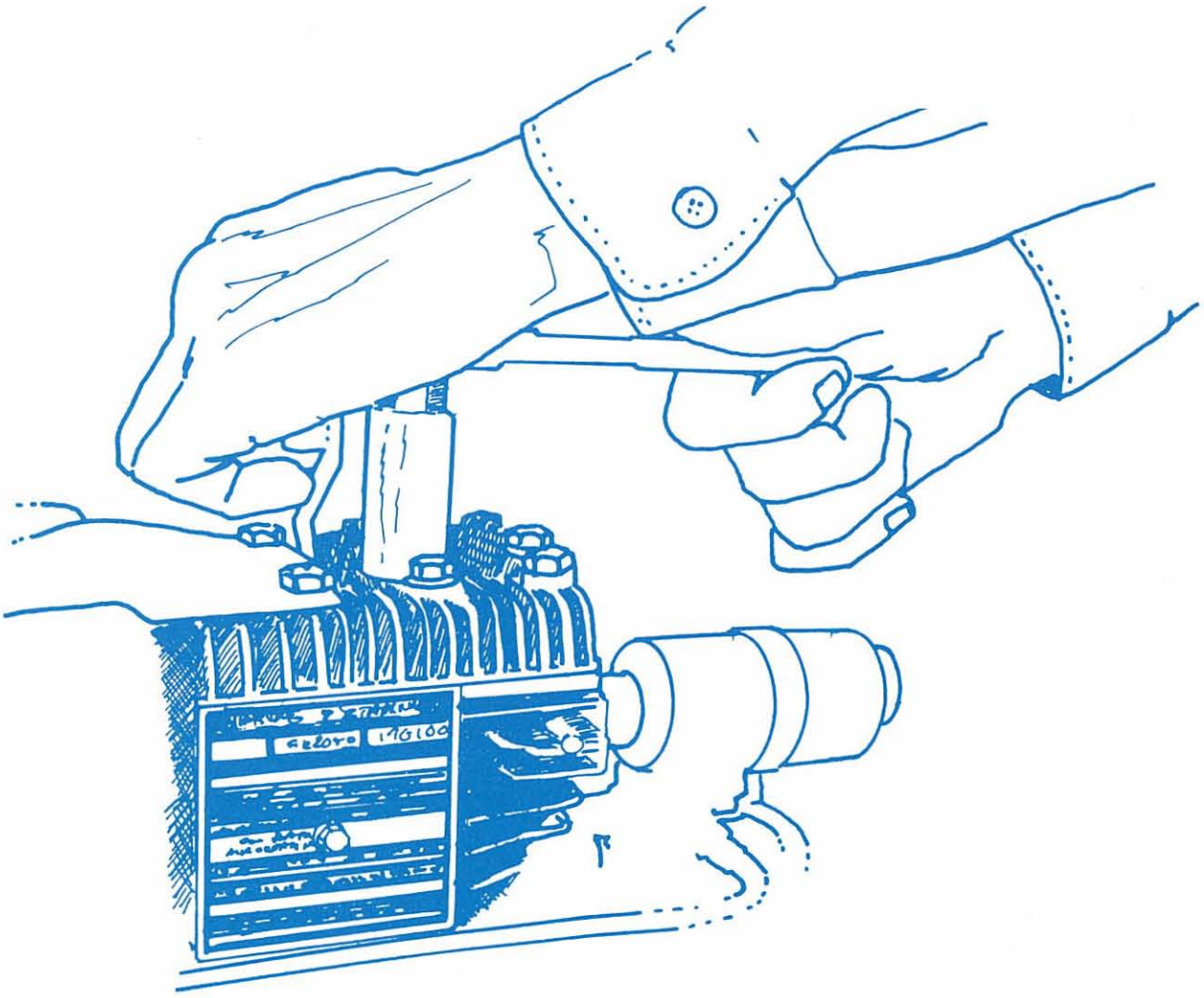


Figure 233

Remove the spark plug as shown in Figure 233. Use a socket head deep plug socket. For most small engines you would use a 13/16-inch deep socket for spark plug removal. Place the socket directly on top of the plug as shown and turn counterclockwise. Always use a socket for removing plugs. Do not attempt to remove them with other type wrenches.

Loosen the plug one full turn and then blow out any dust or dirt around the spark plug hole. This is very important as this recess tends to pick up dirt and foreign matter. If it is allowed to remain when the plug is removed it will fall into the top of the cylinder when the plug is taken out. This could cause damage to the cylinder and the cylinder walls.

Remove the plug and gasket. Sometimes the gasket will stick to the head and not come out with the plug. After the plug is removed, inspect it for damage, burning or other discoloration. Reconnect the high tension wire and ground the plug to the engine frame. Lay the plug on the cylinder head so the metal part will touch some unpainted part of the engine.

Crank the engine one or two turns and check the spark at the electrodes. If the plug is good the spark should be a blue-orange color. There should be a sharp cracking sound when the current jumps the gap. This action indicates the spark plug is good.

If there is no spark or the spark is weak, the trouble could be either in the plug or the ignition system. Remove the high tension lead from the spark plug terminal. Hold the end of the high tension lead about 1/4-inch from the cylinder head and crank the engine. A spark should jump from the high tension lead to the cylinder head if it is producing voltage. If the spark is a blue-orange color the ignition system is good.

CLEANING SPARK PLUGS

Spark plugs can be cleaned either by using a solvent and scraping with a small-bladed knife and wire brush or by using a sand blast machine. Some manufacturers will void the warranty if a sand blast machine is used to clean spark plugs. There is danger of particles of sand remaining in the plug and eventually getting into the engine. If you use a sand blast cleaning method be sure to clean with a solvent or compressed air after using the sand blast.

SPARK PLUG MAINTENANCE

Any condition that reduces the flow of current through the plug and across the gap will affect the operation of the engine. This is particularly true on small engines since most of them have one plug. In a multi-cylinder engine, such as an automobile, a bad plug will sometimes not be too noticeable since the others are carrying part of its load of the engine.

The plug can become fouled with oil, lead or carbon deposits. These deposits provide a path for part of the electric current to by-pass the spark gap. This will result in a weak spark or no spark. Cracked porcelain on the plug will also cause a weak spark.

HOURS OF ENGINE OPERATION	PLUG GAP	SPARK VOLTAGE REQUIRED
0	.025	10,000
20	.026	11,000
40	.027	12,000
60	.028	13,000
80	.029	14,000
100	.030	15,000

Figure 234

SPARK-PLUG WEAR

When a spark plug is new, the edges of the electrodes are sharp and a spark will jump the gap under cylinder pressure with as little as 10,000 volts. As the engine is used, the electrodes wear and the gap is widened. Hot combustion gases and continuous electrical discharges of the spark jumping the gap wears away the electrodes until they become rounded and the gap widens. The gap will increase about .001-inch for each 20 hours of operation.

The chart in Figure 234 shows the increased voltage required to jump the gap in worn spark plugs. When a new plug is installed and gapped at .025-inch it requires a spark voltage of about 10,000 volts to jump the gap. Notice how the plug gap begins to widen after 20 and 40 hours of operation. At 60 hours the gap has increased from .025 to about .028. This small increase of .003 doesn't seem to be very much but notice the voltage required to jump the gap has increased to 13,000 volts. At 100 hours it takes an extra 5,000 volts to jump the gap as the plug increases to .030 inch.

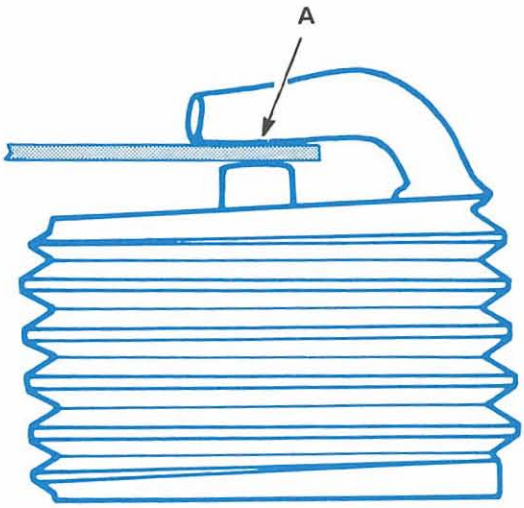
An ignition system in good condition will easily produce 10,000 to 20,000 volts, however, as the system gets older it may have trouble developing enough voltage to fire a worn plug. This makes spark plug maintenance very important in an older engine.

A spark plug not functioning properly will increase fuel consumption, cause crankcase oil dilution, excessive deposits in the combustion chamber, hard starting and, in general, reduce the efficiency of the engine.

SPARK PLUG GAP

Most small engines use a spark plug gap of .025 to .030 inch. This is generally given on the engine name plate along with the ignition point gap. Make all adjustments by bending the ground electrode. This is done by trial, either moving the electrode closer or away from the center electrode.

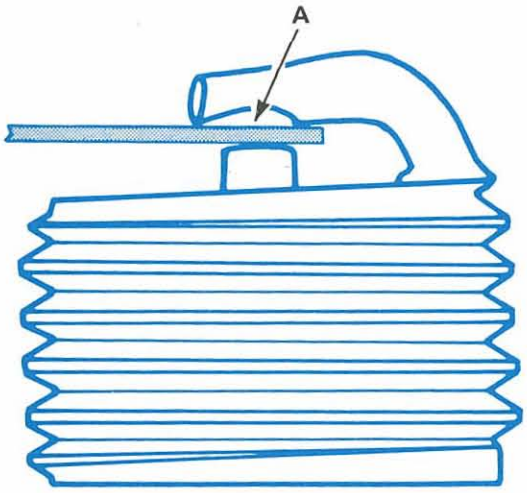
A flat feeler gauge, as shown in Figure 235, may be used for new plugs since there is a flat spot on both the outside electrode and the inside electrode as shown at A.



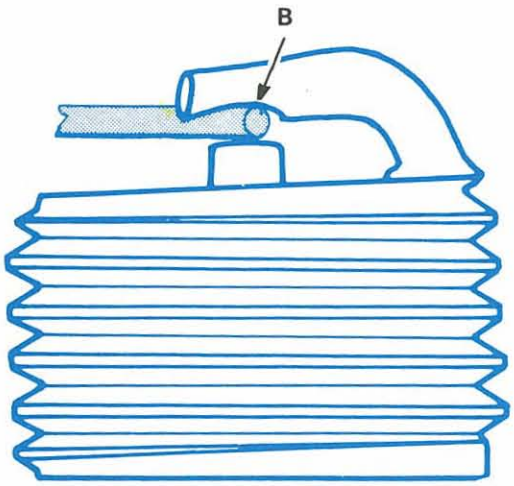
NEW PLUG

Figure 235

CHECKING GAP



WRONG



RIGHT

Figure 236

If plugs have been used and it is necessary to regap them, you should use a wire feeler gauge. As we mentioned earlier, the constant arcing of the spark across the electrodes eats away or corrodes the electrodes causing the condition shown in Figure 236.

If a flat feeler gauge, as shown at A, were used it would not give a true reading because of the worn part of the electrode shown at A.

When a round or wire gauge is used, you can get a true reading as shown at B. The flat feeler gauge tends to bridge over the gap which results in the gap being too wide. A wire feeler gauge will avoid this.

INSTALLING SPARK PLUGS

It is always advisable to use a new gasket when reinstalling the same plug back into the engine. There are some plugs that do not have gaskets. They have a tapered seat that fits the cylinder head. Without a gasket a spark plug designed to be used with a gasket may enter too far into the combustion chamber and cause damage. Spark plugs should be tight but not too tight as there is danger of stripping the threads. This is especially true with aluminum heads that are being used on many engines.

TORQUE RECOMMENDATIONS FOR TIGHTENING SPARK PLUGS			
SPARK-PLUG THREAD AND SIZE	TORQUE WRENCH CAST-IRON HEAD	TORQUE WRENCH ALUMINUM HEAD	WITHOUT TORQUE WRENCH COOL ENGINE
10mm (3/8"+)	12-15 ft-lbs	10-11 ft-lbs	* 3/4 to 1 turn
14mm (9/16"—)	25-30 ft-lbs	22-27 ft-lbs	* 1/2 turn
18mm (11/16"+)	30-40 ft-lbs	25-35 ft-lbs	* 1/2 to 3/4 turn

(*) Number of turns beyond finger tight.

Figure 237

The table in Figure 237 shows the recommended torque wrench tightening for the average small engine plugs. If you do not have a torque wrench you can use the wrench method shown in the column on the right. These specifications are general but can be used for most small engines.

NEW SPARK PLUGS

Unless a spark plug is in very good condition and requires practically no cleaning it is recommended to replace it with a new one when at all possible. It takes very little time and the cost is small compared to the advantages to be gained. With a new plug of the correct type and properly gapped, you can be almost assured of better engine operation. Most all good shops will always replace spark plugs with a new one if there is any degree of wear present.

There is a slight difference in spark plug design for 2-cycle and 4-cycle engines. Figure 237A shows the recommended plug design for these two engines.

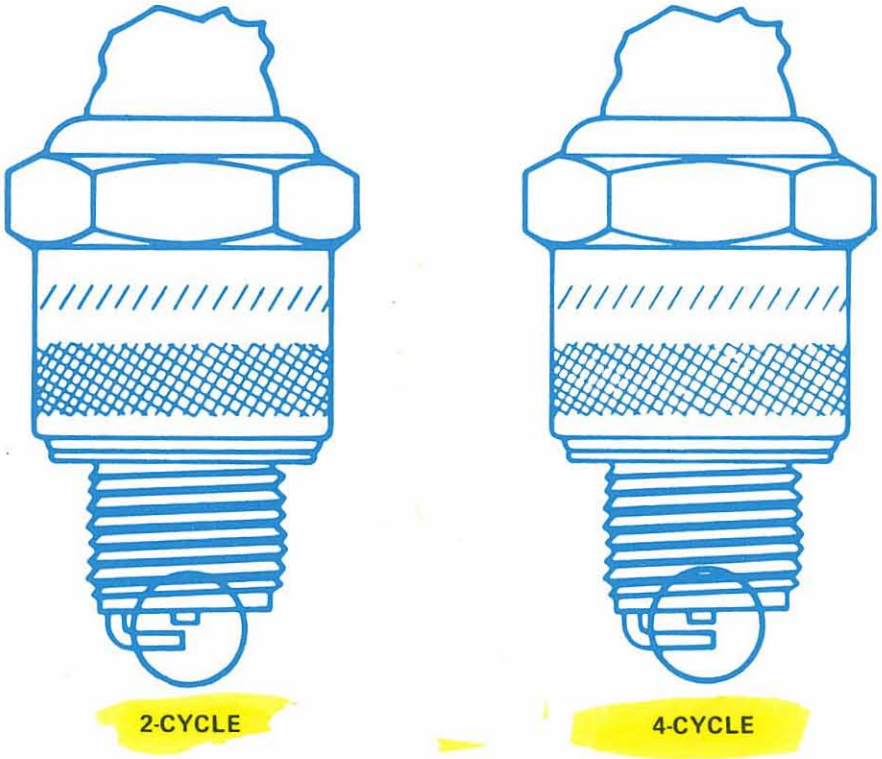
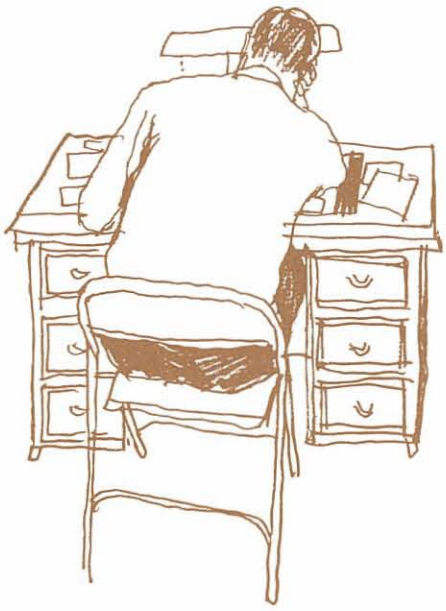


Figure 237A



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

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EXAMINATION ON LESSON 24
SPARK PLUGS

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. When spark plugs overheat, they tend to burn the _____. _____
   a. combustion chamber
   b. insulator
   c. electrodes

2. A spark plug that is not functioning properly can cause _____. _____
   a. crankcase oil dilution
   b. increased fuel consumption
   c. hard starting
   d. all of the above

3. Spark plugs are designed for normal, hot, or cold operation. _____
   TRUE
   FALSE

4. The spark plug designed for the two cycle and four cycle engines are the same. _____
   TRUE
   FALSE

5. The threads of a spark plug will collect carbon deposits if they are too long. _____
   TRUE
   FALSE

6. The _____ tension wire carries voltage from the magneto to the spark plug. _____
   a. high
   b. low
   c. neither of the above

7. If a spark plug is good, the spark should be a _____ color. _____
   a. blue/orange
   b. blue/red
   c. orange/red

8. A fouled spark plug is caused when carbon deposits form between the center electrode and the ground electrode. _____
   TRUE
   FALSE

(Continued on page 2)

9. The spark plug provides a means for a spark to occur inside the _____ area of the engine. _____
   a. crankcase
   b. carburetor
   c. combustion chamber

10. The gap between the electrodes should be between _____ to _____ on most small engines. _____
    a. .010″ to .015″
    b. .025″ to .030″
    c. .045″ to .050″

11. A spark plug reach must be the proper distance to fit the different depths of engine heads. _____
    TRUE
    FALSE

12. The _____ electrode carries the voltage from the high tension wire to the spark plug gap. _____
    a. side
    b. center
    c. neither of the above

13. All spark plug adadjustments are made by bending the _____ electrode. _____
    a. positive
    b. negative
    c. ground

14. The AC plug S42 is interchangeable with the Champion plug _____. _____
    a. J-4J
    b. F20
    c. 2HL
    d. none of the above

15. All spark plugs have gaskets between the plug and the head. _____
    TRUE
    FALSE

16. Small deposits on spark plug electrodes will result in a _____ spark. _____
    a. weak
    b. strong
    c. makes no difference

17. The spark is timed to ignite the fuel and air mixture at the proper time, when it is under compression. _____
    TRUE
    FALSE

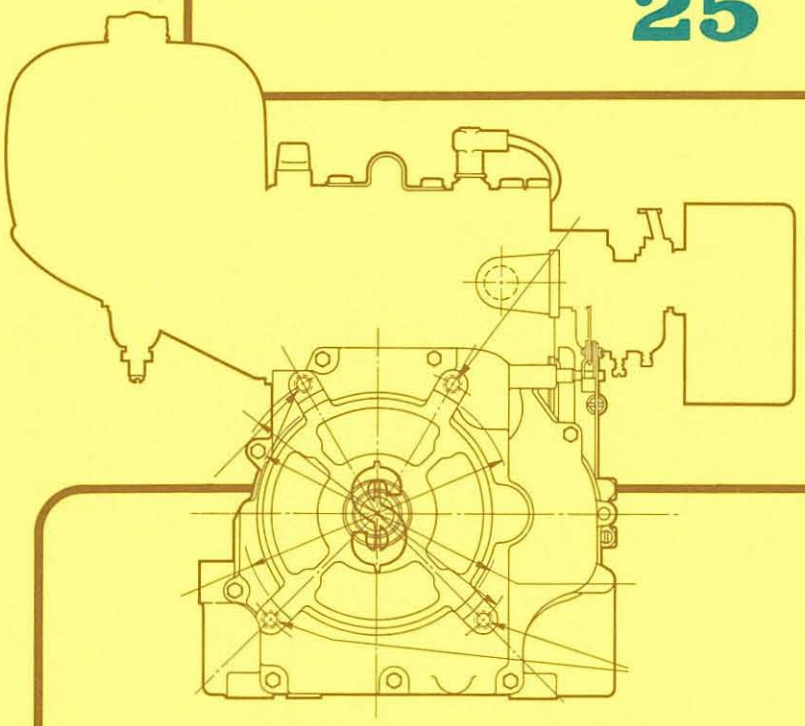
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

25



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...and let's find out all about --

THE MAGNETO AND FLY WHEEL

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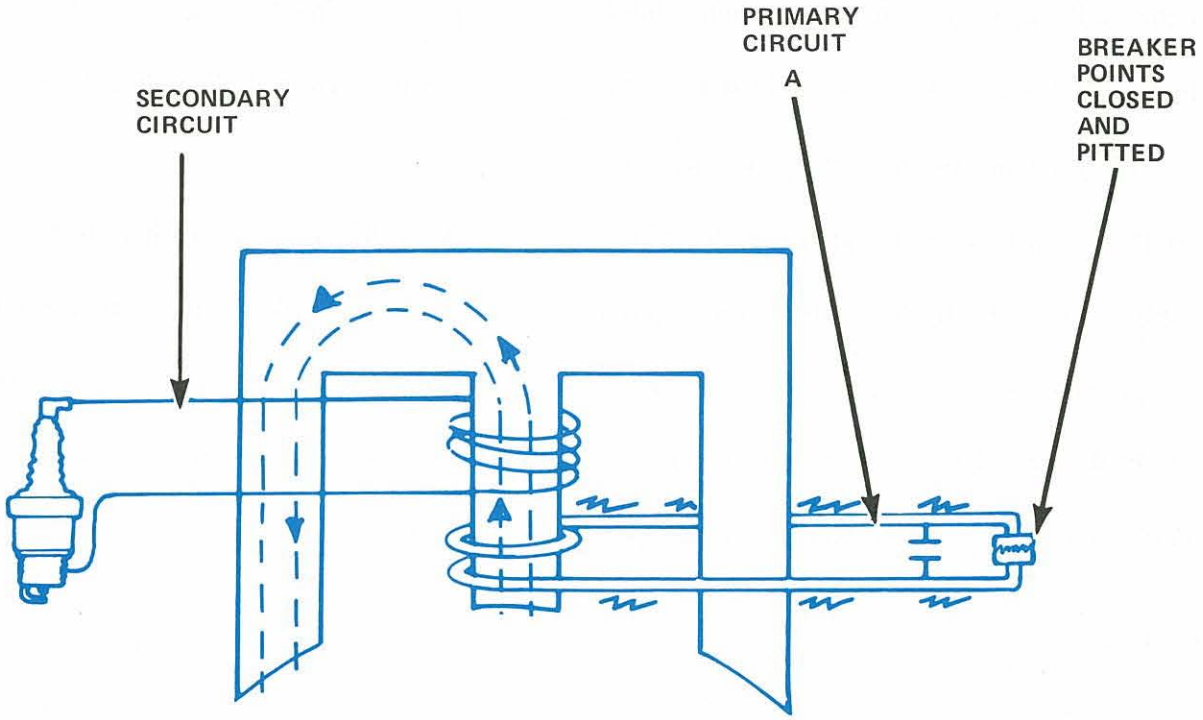


Figure 238

MAGNETO MAINTENANCE

The ignition system on small engines must be electrically sound and in good mechanical condition if the engine is to function properly. Since the magneto supplies the voltage necessary to produce the spark to ignite the spark plug it is very important for the magneto to be operating at full capacity for efficient operation of the engine.

The breaker points must be clean and in good condition. Dirty, pitted or corroded points will slow the original build-up of current in the primary circuit because they make a poor electrical connection and resist current flow.

Earlier in the study of the principles of the magneto, we learned that when the breaker points were closed it caused a build-up of current in the primary circuit. Figure 238 shows the breaker points closed and the primary circuit current build-up. If these breaker points were pitted, dirty, corroded or in general bad condition they would make a poor electrical connection and resist the flow of current. With the flow of current restricted the primary circuit electrical charge, shown at A, would be reduced. This, in turn, would reduce the charge of the secondary circuit.

Figure 239 shows the points in the open condition. The charge has been released to the secondary circuit to fire the spark plug. The points are open, as shown at A, and the plug is ready to fire at B. If the points at A were pitted the primary circuit charge would be low which would also cause the secondary circuit to be low. This would give a lower voltage to the spark plug, making the engine hard to start or preventing it from starting altogether.

When the points open there will not be a sharp, clean-cut break to speed the breakdown of the primary circuit if the points are pitted or dirty. The result of this will be a weak voltage at the spark plug.

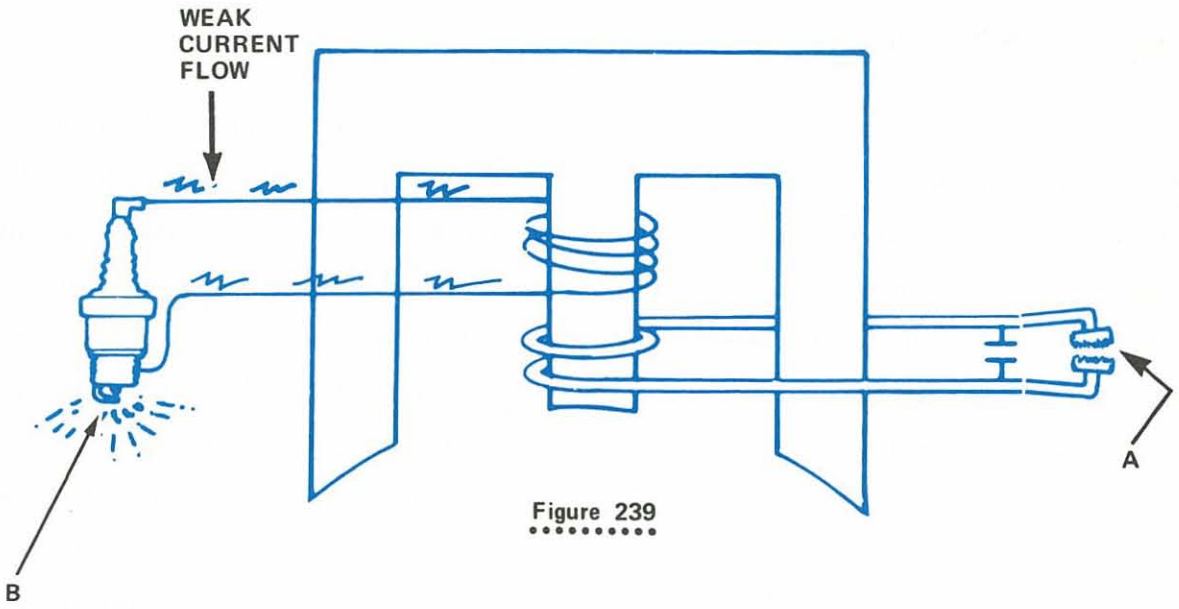


Figure 239

TEST PLUG

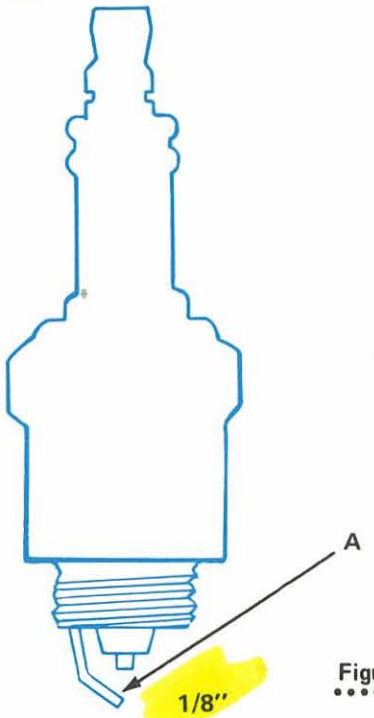


Figure 240

CHECKING MAGNETO OPERATION

The easiest way to check a magneto output is with a spark plug. To be sure the spark is adequate, even for a slightly worn or fouled plug, a special plug can be used to test the magneto strength. Normally, small engine spark plug gaps would be set at .025 to .030 inch. If we used a test plug, as shown in Figure 240, and the spark jumped the gap we could be reasonably sure the magneto was giving adequate voltage to ignite the plug.

This is a regular spark plug with the ground electrode opened to 1/8 inch as shown at A. If the magneto has adequate voltage to jump the 1/8 inch gap easily, you can be reasonably sure that it is producing adequate voltage to ignite the plug.

Figure 241 shows how you can adapt a regular spark plug for use as a magneto test plug. First, the ground electrode is bent out as shown in Figure 240. Use two alligator clips as shown. The larger one is a Number 27 Mueller and the smaller one is a Number 45.

Remove the two screws and attach these clips together as shown in Figure 241. The larger clip is locked to the spark plug and the smaller one is attached to the engine block. Usually one of the cooling fins on the head is the best place. Attach the high tension wire to the spark plug terminal and crank the engine. If you get a good strong spark across this 1/8 inch gap the magneto should be providing adequate voltage to ignite the spark plug.

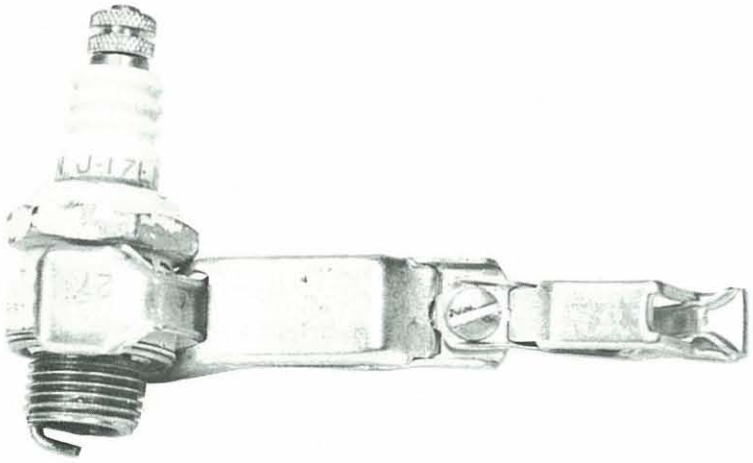


Figure 241

If the spark is weak or none at all, check all visible wiring for looseness and the possibility of shorting. Loose connections will cause a lower voltage to reach the spark plug. Short circuits, caused from worn insulation and exposed wire touching some part of the engine will allow current to go direct to ground instead of to the spark plug.

Replace any damaged or oil-soaked insulation with new wiring. If the ignition switch is grounded, the secondary circuit will go direct to ground instead of jumping the gap at the plug. Electricity will always follow the path of least resistance. A direct short or connection to ground is always less resistance than jumping the gap at the plug.

If a good spark occurs regularly, it is likely the magneto is good. If there is no spark or the spark is weak, it will be necessary to remove the flywheel on some flywheel magnetos, to get at the points, condenser and other operating parts. Most of the small engines used on lawnmowers, snowblowers and other similar applications will have the magneto parts mounted inside the flywheel.

FLYWHEEL REMOVAL

Disconnect the spark plug wire and remove the starter and shroud assembly as shown in Figure 242. First remove the gas line from the carburetor. On many of these engines the fuel tank will have to be removed first as the bolts holding the shroud to the engine are behind the fuel tank. Remove the bolts holding the shroud to the engine. Lay these bolts out in order along with the other bolts as shown in Figure 242. Sometimes these bolts are of different lengths and they have to be replaced in the proper hole.

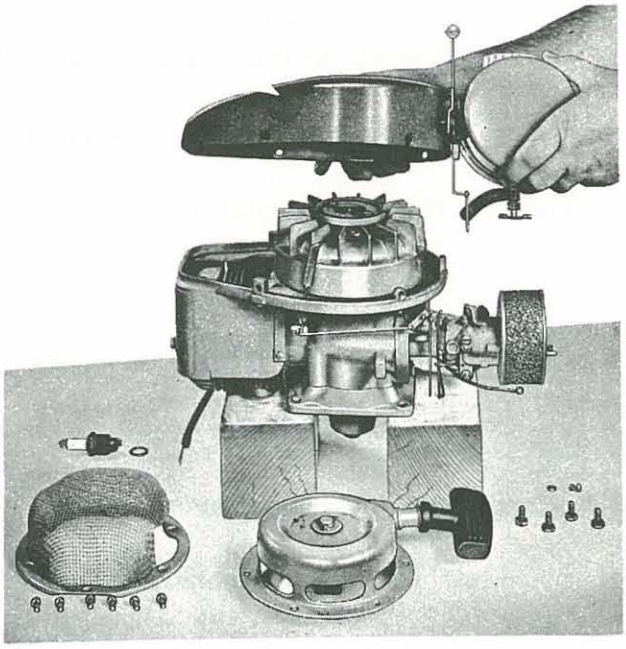


Figure 242

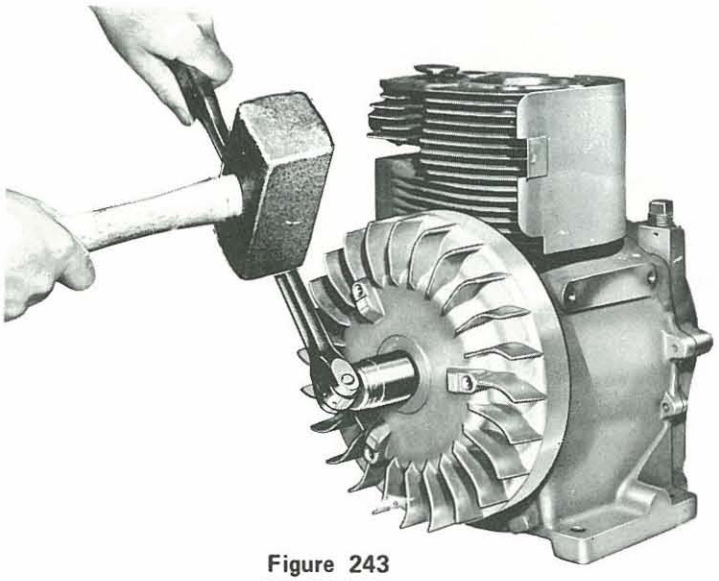


Figure 243

Remove the flywheel nut, as shown in Figure 243. Use a socket and long handle extension as shown. It will sometimes be necessary to tap the wrench handle with a mallet as shown. Generally this method will loosen the nut on flywheels, however, if the nut has become rusty and possibly frozen it may be necessary to use some method of holding the flywheel to keep it from turning.

Figure 244 shows the use of a flywheel holding tool. This tool fits the slots in the air fins of the flywheel and around the outside to keep it from turning as the nut is removed. Seldom is it necessary to use this tool since most flywheel nuts can be removed by the method shown in Figure 243.

If it is necessary and a flywheel tool is not available, you can use a piece of 1-inch belting around the flywheel to hold it. Never use a screw driver or other tool to hold the flywheel at the air fins. These are easily broken. Most of these engines have right-hand threads. The nut is tightened by turning to the right or clockwise. Turn counterclockwise for removing the nut. One way to remember the proper direction when loosening a flywheel nut is to turn the nut in the opposite direction of engine rotation.

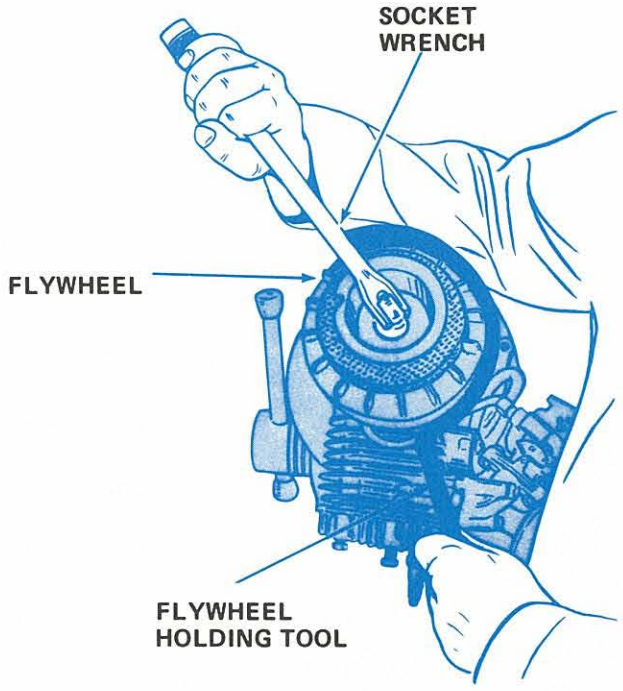


Figure 244

After the nut has been removed the flywheel can be removed. There are two methods of removing the flywheel from the crankshaft. You can use either an impact nut, sometimes known as a wheel knocker, or a flywheel puller tool.

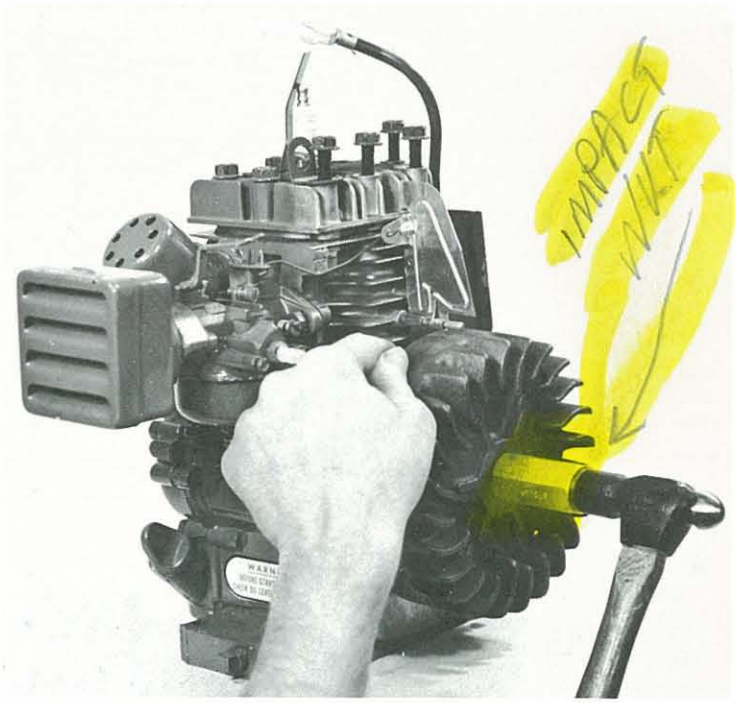


Figure 245

Figure 245 shows the use of an impact nut. This nut is made of a piece of steel about two inches long and threaded on the inside to the same thread as the crankshaft. To use this tool, thread the nut all the way on, just hand tight. Then back off one complete turn and strike a solid blow with a hammer as shown. Lift up with one hand as you strike the nut and the flywheel should be free of the shaft. Never use the flywheel nut instead of an impact nut. There is danger of cracking the shaft and damaging the threads. Always use the impact nut. There are several different sizes used but 7/16 and 1/2 inch will fit the majority of small engines up to about 5 horsepower. It is always best to use a plastic or lead hammer when using an impact nut. These soft face hammers have less tendency to allow the hammer to slide off at an angle which could break or damage the threaded end of the shaft.

Always try to hit the impact nut one sharp solid blow. Too much hammering or vibration of the flywheel can destroy the magnetism in the flywheel. A good sharp blow on a magnet will sometimes cause it to lose its magnetism because it disturbs the magnetic lines of force.

FLYWHEEL PULLER

Most flywheels used on small engines are tapered and the impact nut is adequate, however, some engines have a straight shaft and it is sometimes best to use a special flywheel puller as shown in Figure 246.

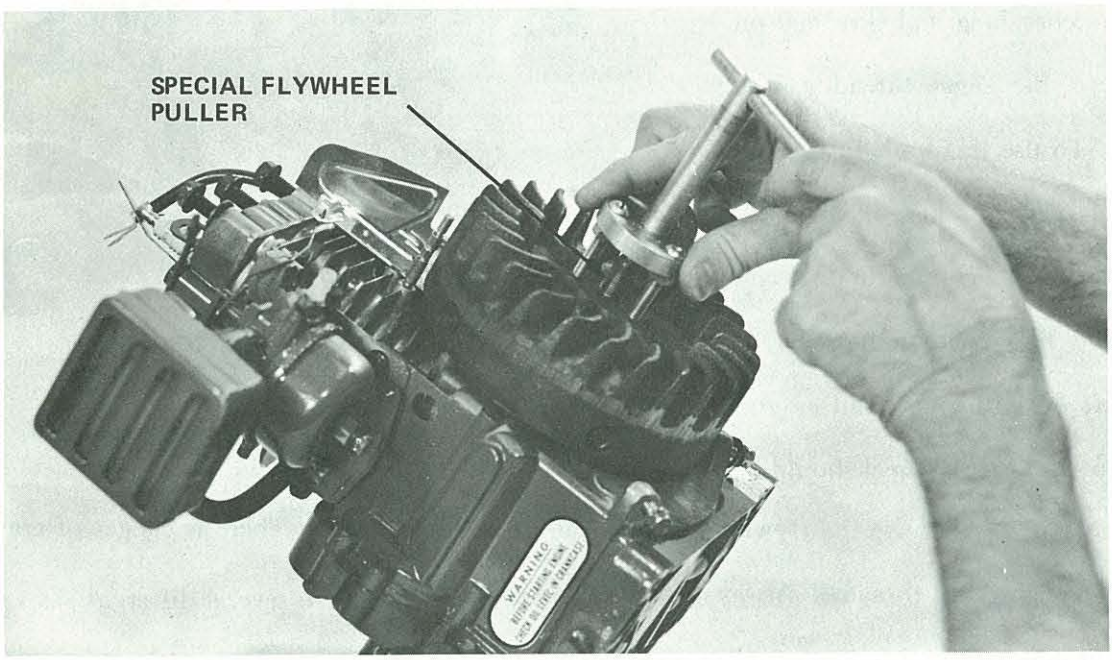


Figure 246

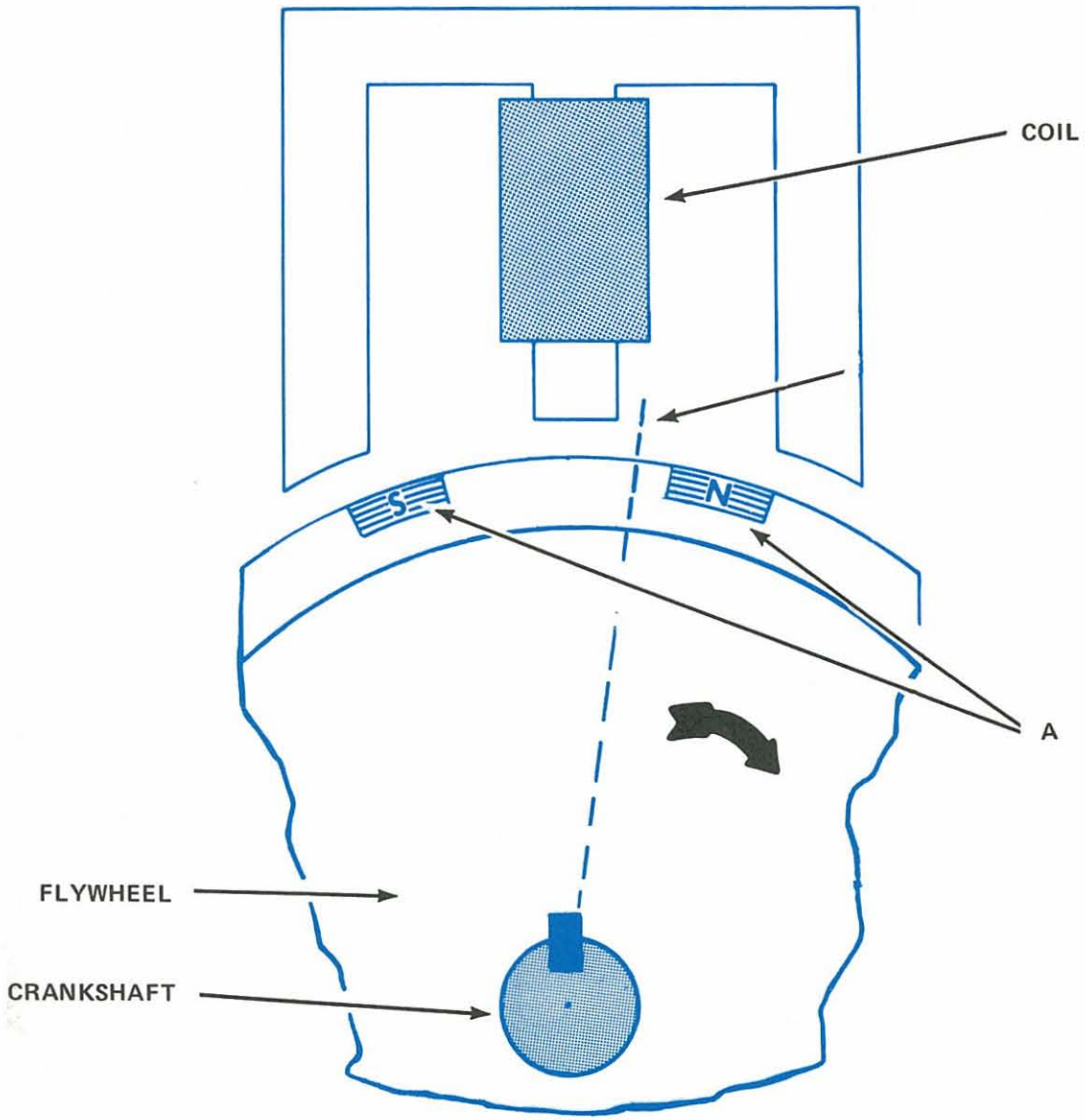


Figure 247

FLYWHEEL INSPECTION

After the flywheel has been removed, check it for cracks, wear or damage. Check for a partially sheared key or damaged keyway in the flywheel. A partially sheared key can cause the ignition timing to be off. The points will not open at the proper time.

Figure 247 shows the position of the crankshaft and flywheel key as it should be for proper operation. Ignition should fire when the magnet is in the position shown at A if the key and keyway of the flywheel are not damaged.

Figure 248 shows what happens if the key is partially sheared or damaged. The key shown at A has been partially sheared. This causes the magnet to be in the position shown at B when the ignition fires.

As we will cover later, the ignition is timed to the ignition points and, if they are not exactly correct, ignition will occur just before or after the proper time. This results in loss of efficiency and hard starting.

The next check of the flywheel is the strength of the magnets. If they are strong enough to attract a piece of metal, such as a screwdriver, they should be adequate. If the pull is enough to give a sharp action in drawing the screwdriver to the magnets, they could be considered strong enough.

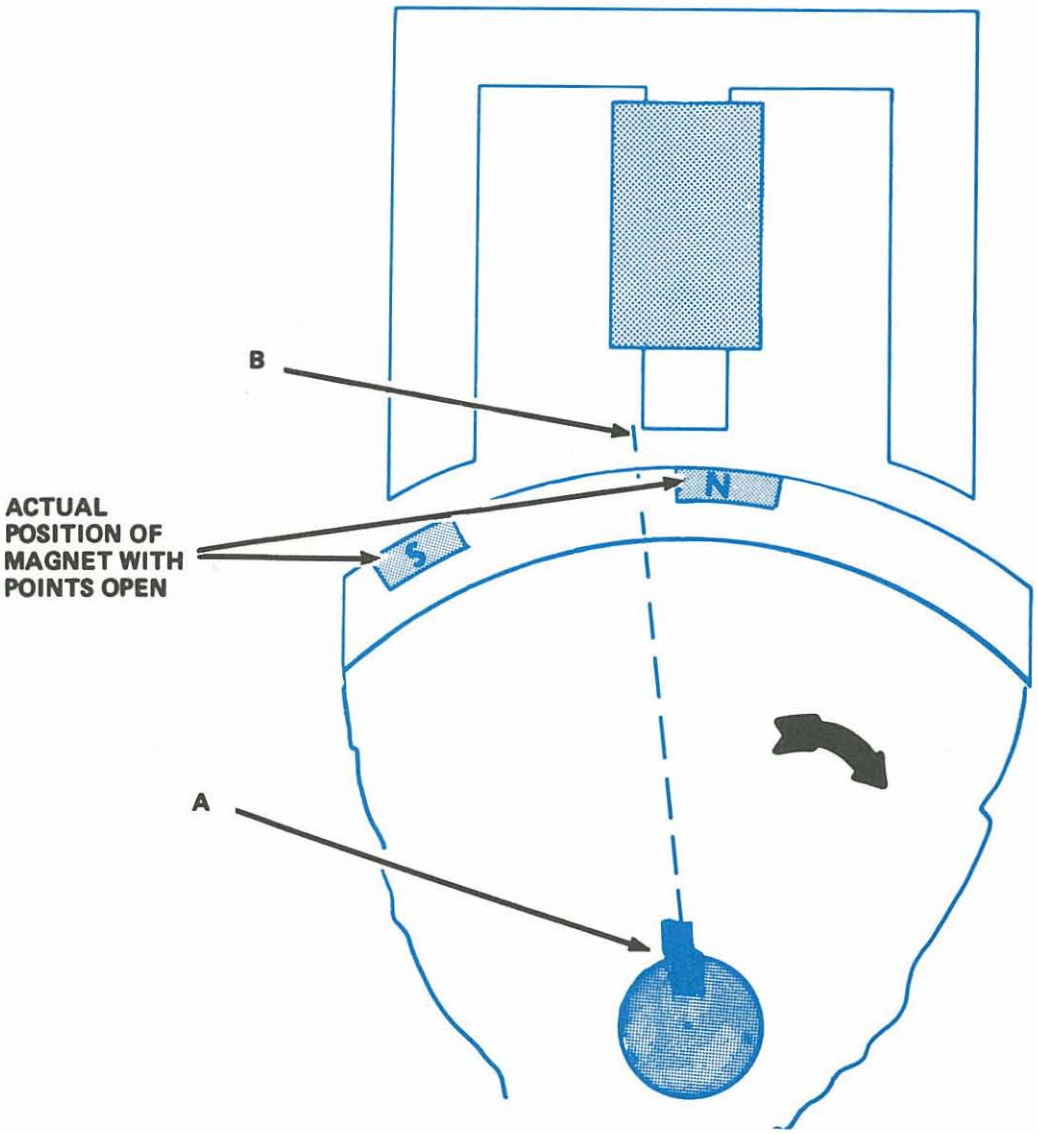
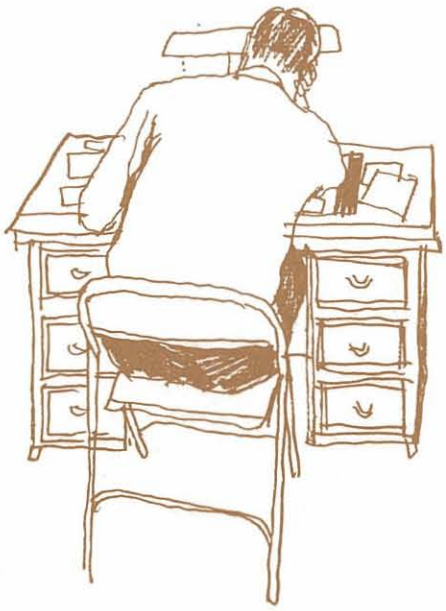


Figure 248



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Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

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EXAMINATION ON LESSON 25
THE MAGNETO AND FLY WHEEL

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Short circuits will allow current to go direct to ground, instead of the spark plug. ____
   TRUE
   FALSE

2. A practically sheared flywheel key can cause the ignition timing to be off. ____
   TRUE
   FALSE

3. When the points are in the open position, the charge is released to the _____ circuit to fire the spark plug. ____
   a. primary
   b. secondary
   c. neither of the above

4. If a good spark occurs regularly, the magneto should be good. ____
   TRUE
   FALSE

5. Dirty, pitted, or corroded points will slow down the original buildup of current in the primary circuit and resist current flow. ____
   TRUE
   FALSE

6. A direct short to ground is more resistance than jumping the gap at the spark plug. ____
   TRUE
   FALSE

7. If a magneto has adequate voltage to jump 1/8" gap, it should ignite th spark plug. ____
   TRUE
   FALSE

8. When the breaker points are closed, there is a buildup of current in the secondary circuit. ____
   TRUE
   FALSE

9. To much hammering or vibration on the flywheel can destroy the magnetism in the flywheel. ____
   TRUE
   FALSE

(Continued on page 2)

10. Electricity will follow the path of _____. _____
    a. most resistance
    b. least resistance
    c. makes no difference

11. Loose connections will cause a lower voltage to reach the spark plug. _____
    TRUE
    FALSE

12. When the points are _____ the spark plug is ready to fire. _____
    a. closed
    b. open
    c. both of the above

13. If the points are pitted, the primary circuit charge would be low which would cause the secondary circuit to be _____. _____
    a. low
    b. high
    c. neither of the above

COURSE Of

Small Engine

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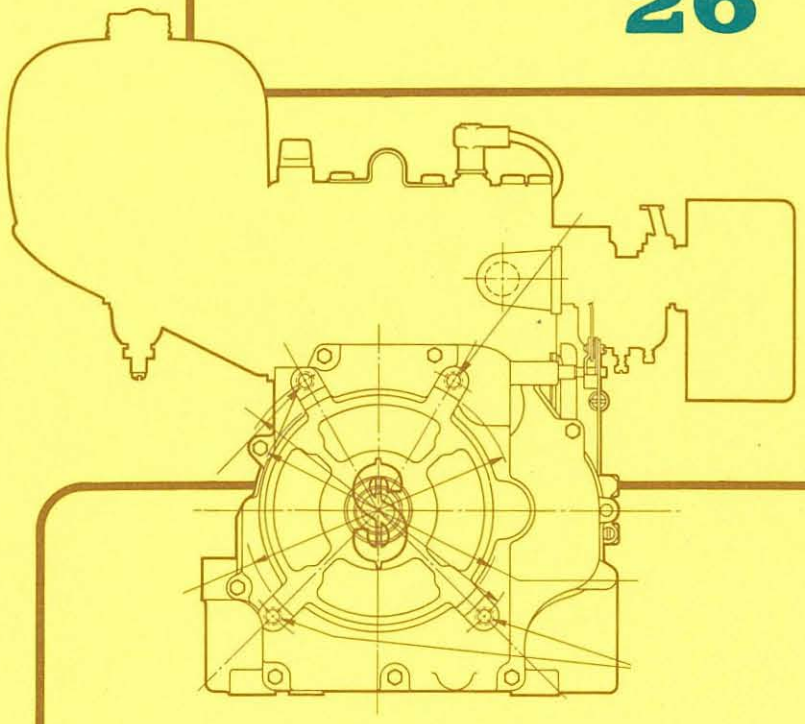
LESSON NUMBER

26



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...and let's find out all about -- **BREAKER POINTS**

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TYPES OF BREAKER POINTS

Some breaker points are located on the side of the engine but most will be located under the flywheel as shown in Figure 249. Most breaker points will be covered with a dust cover which must be removed to gain access to the points and condenser. Before removing this dust cover, be sure to clean and blow off any dust and dirt. Use a clean cloth with a small amount of solvent to remove any grease. Generally wiping clean with a dry rag is adequate.

Most contact points on small engines will operate direct from the crankshaft. They can be operated by other mechanical actions but they must be timed to the rotation of the crankshaft.

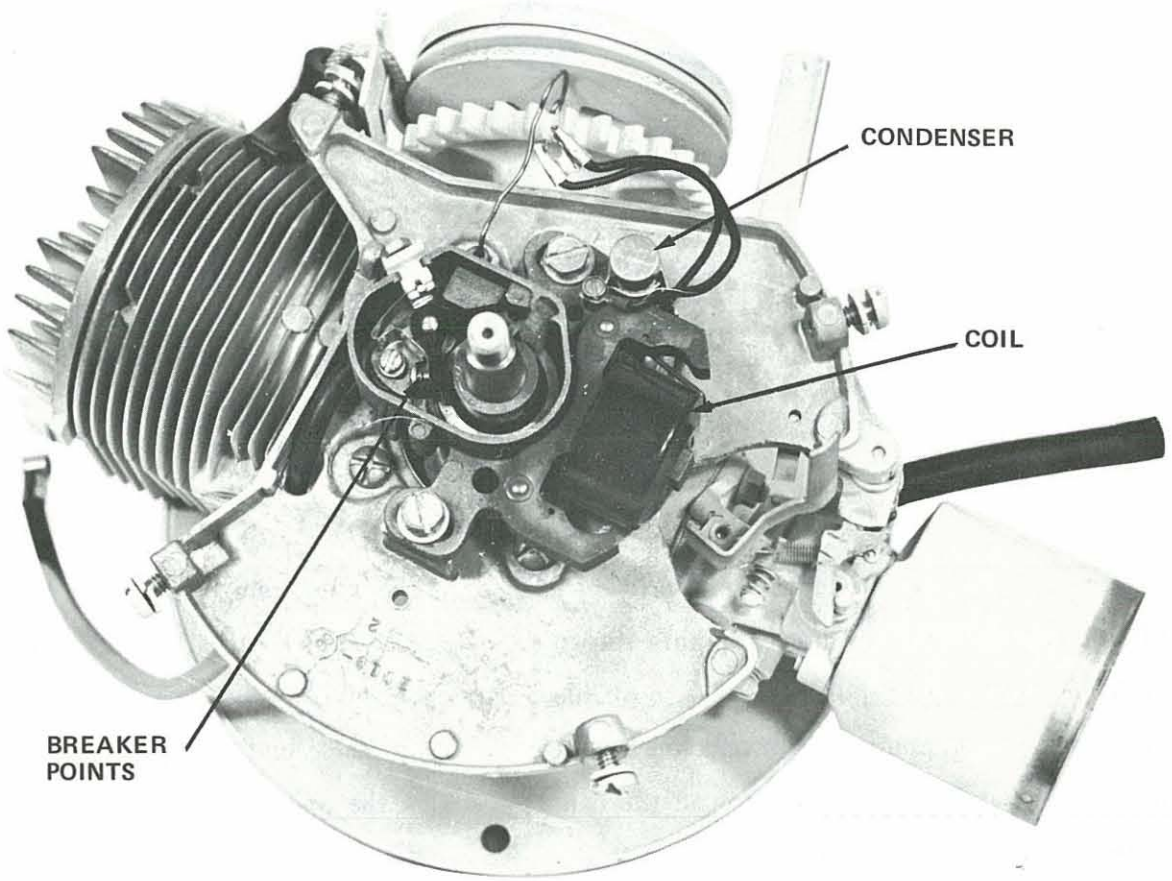


Figure 249

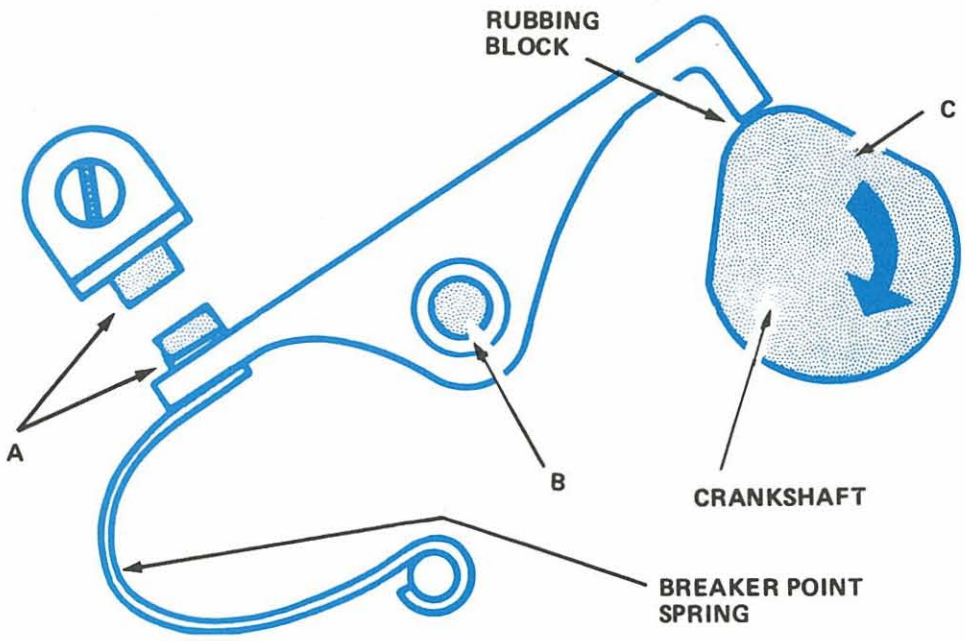


Figure 250

Figure 250 shows the basic mechanical principles of the contact points. The breaker points, shown at A, are in the open position. The moveable part of the contact points is positioned on a pivot post shown at B. This part rides on the cam shown at C. The cam is attached directly to the crankshaft and held with a key so it will turn with the crankshaft. Notice there is a high spot on the cam. In the position shown, it pivots the moveable part of the contact points so they are in the open position. As long as the cam is in this position, the points should be open.

As the crankshaft turns the cam will turn. Figure 251 shows the action of the points as the cam turns. When the rubbing block, shown at A, is riding on the low part of the cam, the moveable side of the contact points pivot and close the breaker points as shown at B. This happens every revolution of the crankshaft.

The cam may be machined on the crankshaft or it may be a separate collar locked on with a key. If the cam is a separate part, be careful not to install it upside down. If this happens the points will open 180 degrees ahead of time. The cam will be marked with the direction of rotation so look for this when reinstalling the cam. In most cases, because of the tapered crankshaft the cam cannot be installed wrong.

The breaker point spring, shown at C, maintains constant pressure to hold the points tight together. Each time the cam turns it flexes this spring. If the spring were too weak or broken, the contact points would not close when the cam was in the position shown in Figure 251.

There is another type of contact point opening mechanism that operates just the opposite as the one shown in Figure 251. It accomplishes the same purpose except the mechanical action is different and it incorporates the condenser body as part of the mechanical action.

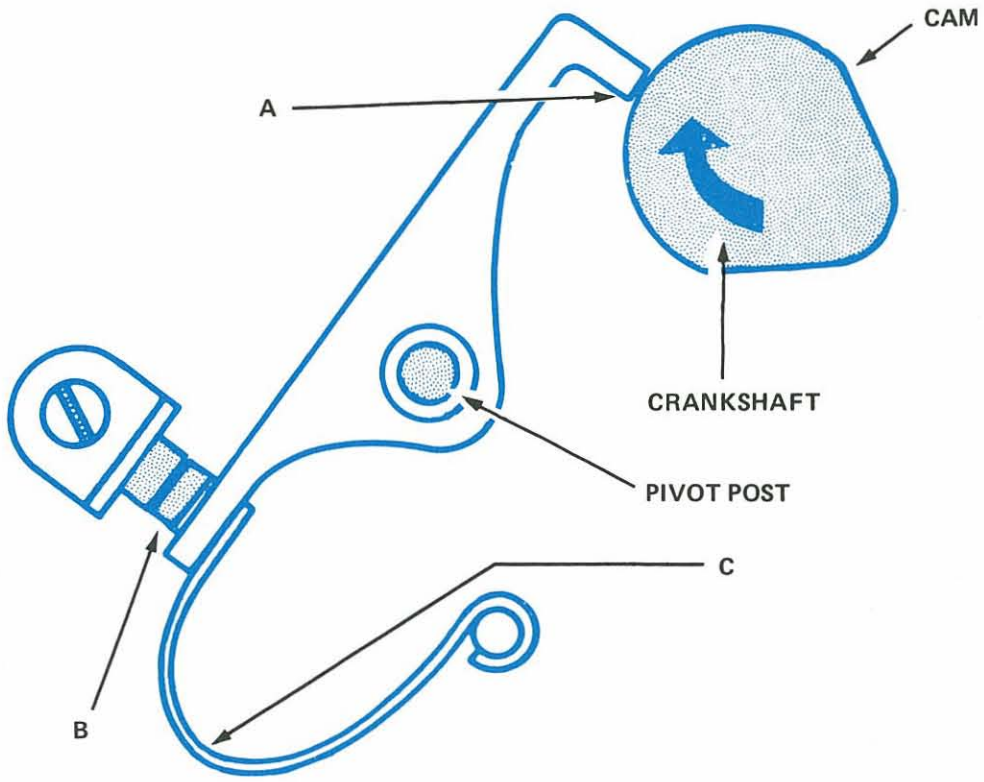


Figure 251

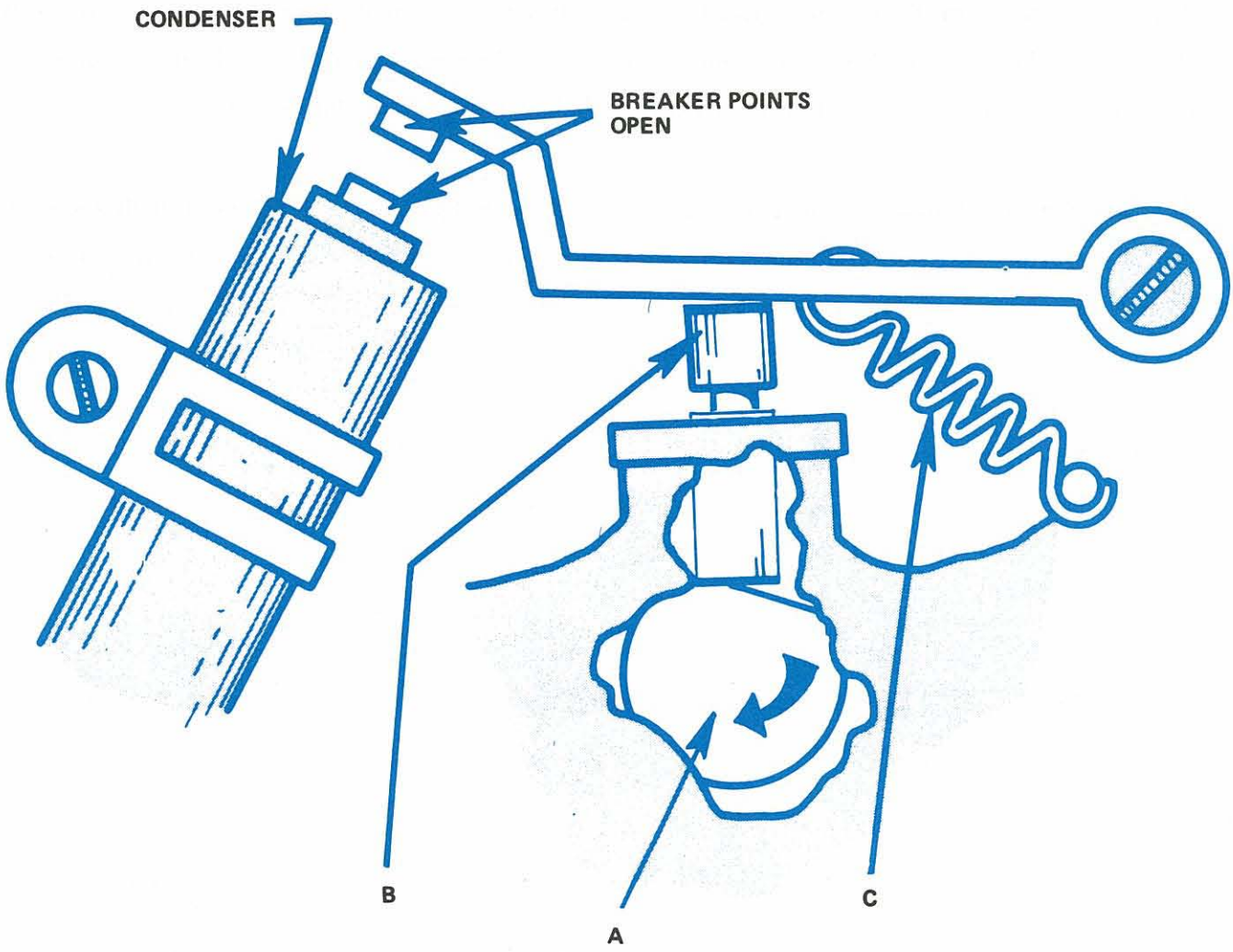


Figure 252

Figure 252 shows the push rod operated mechanism. The crankshaft, shown at A, has a flat spot on it instead of the raised cam shown at Figure 251. The push rod, shown at B, rides on the crankshaft. When the push rod is riding on the shoulder as shown or on the round part of the crankshaft it opens the contact points. Tension is exerted on the contact point with the coil spring, shown at C, instead of the flat spring used in the other action. One part of the breaker points is actually part of the condenser body.

As the crankshaft turns, the push rod will ride on the flat spot of the shaft as shown in Figure 253. This lets the push rod A move down because the spring B closes the points when the push rod is down. This closes the contact points shown at C.

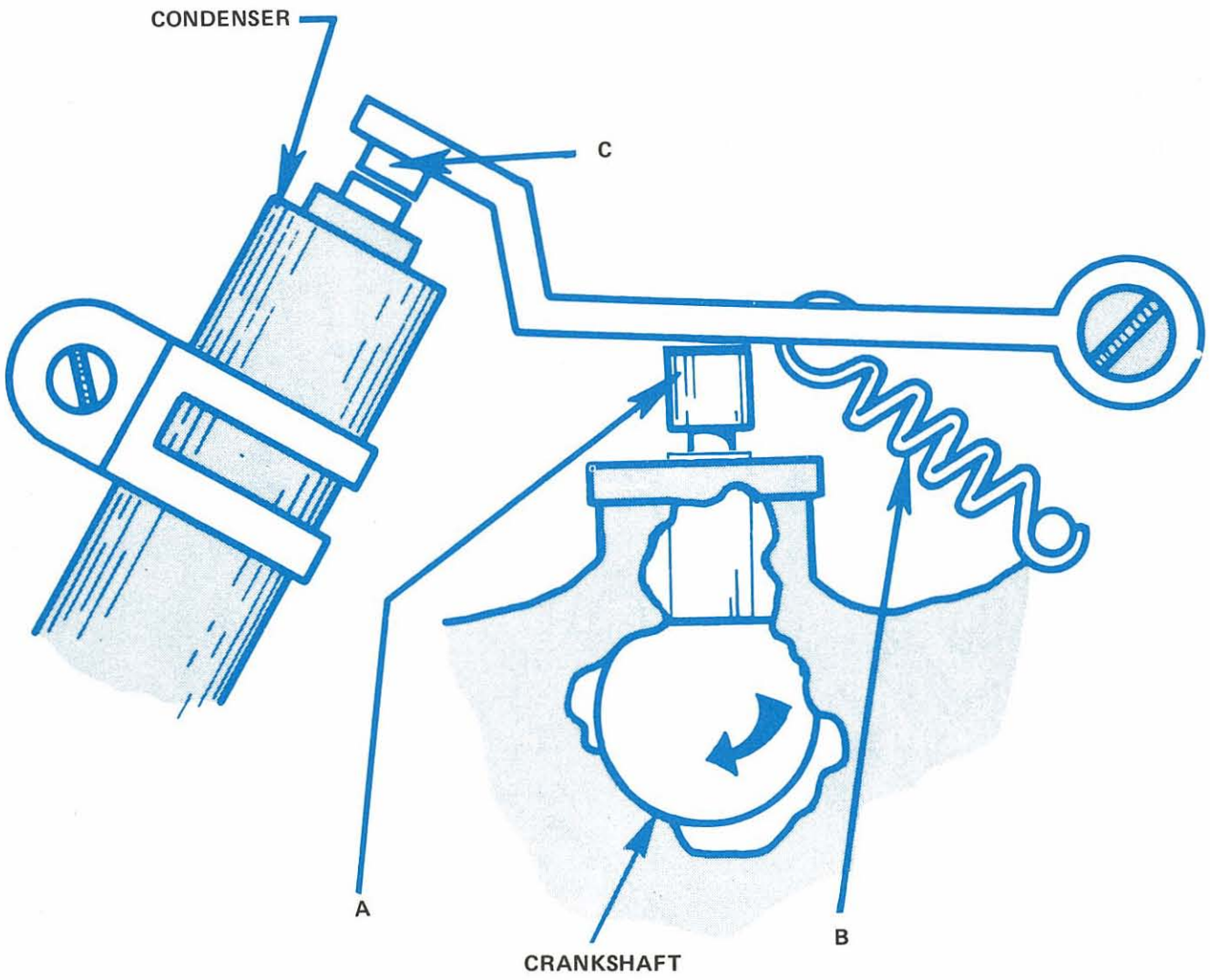


Figure 253

As the crankshaft turns further it will raise the push rod and open the points. This push rod is the part most likely to need replacement, in addition to the contact points. There are other similar methods used to obtain this mechanical action, however, the basic principles are very much the same.

BREAKER POINT ASSEMBLY INSPECTION

After you remove the cover plate from the breaker point assembly you should first check the parts shown in Figure 254. The cam shown at A will seldom show wear or cause trouble because it is much harder than the other parts operated with it. There is a small piece of felt material shown at B that is held in place by a slot in the casting holding the assembly. This felt rides against the cam as shown and is used to lubricate the cam. A very small amount of light weight oil is all that is necessary. About one drop should be good for the entire season. Be sure this has not slipped out of place and that it rides on the cam.

The next wear spot is the rubbing block shown at C. This is a piece of bakelite material that is softer than the cam. Since it rides on the cam under spring pressure there is a good possibility of wear. We'll cover the points shown at D later.

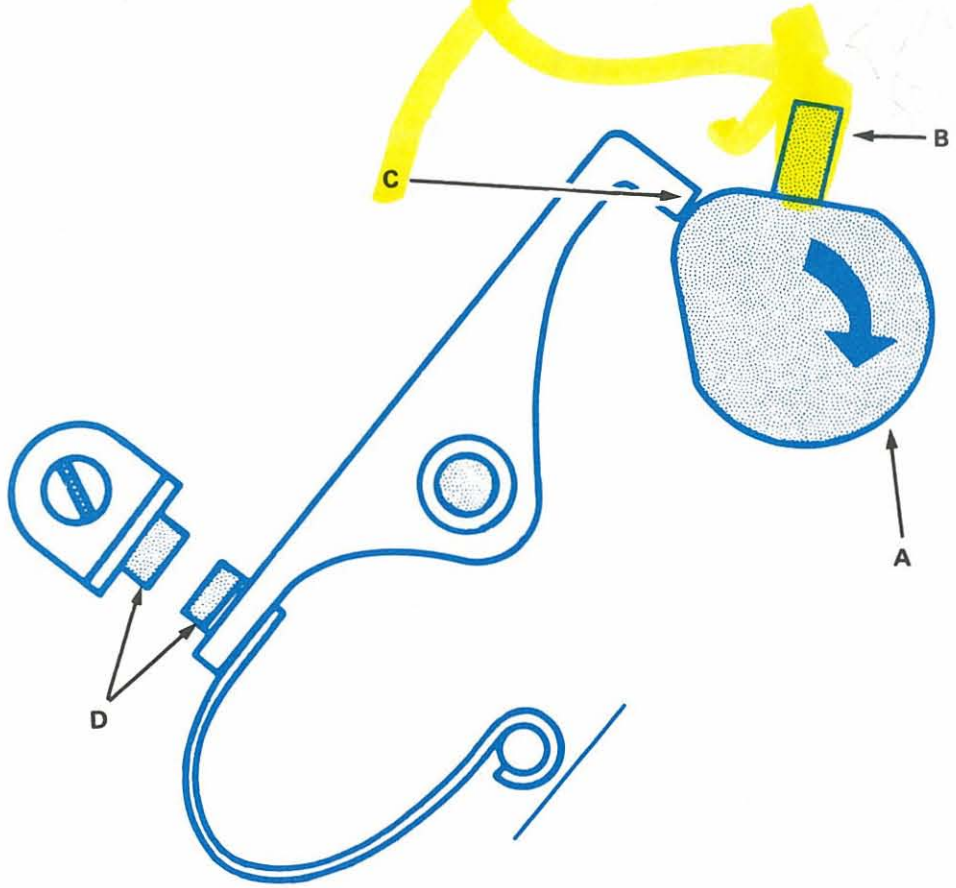
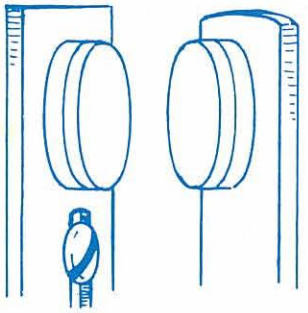


Figure 254

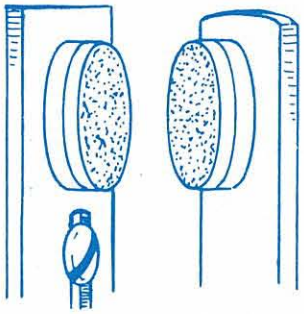
Directly under the cam there is an oil seal. The inside of the crankshaft is running in lubrication and this seal keeps oil from leaking out into the contact point housing. Inspect the inside of the point housing for signs of oil. If oil is present it will be necessary to replace the oil seal. If oil gets on the contact points it will ground the points. Check the condition of all wiring.

BREAKER POINT CHECK

The surface of the breaker points should be smooth and flat with no pits or rough spots as shown in Figure 255. The points shown at A are smooth and clean. If the points are rough, but show only a slight amount of pitting, as shown at B, they can be smoothed with an ignition file. An ignition file is similar to a regular finger nail file except it is made of much harder metal and has a square end.



A



B

Figure 255

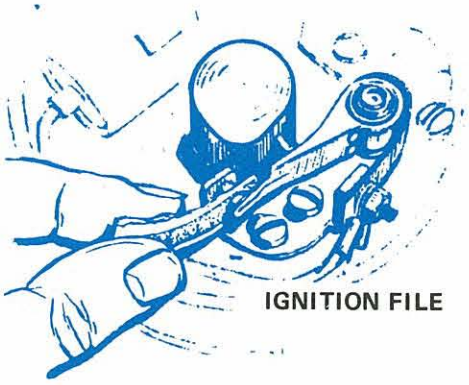


Figure 256

If only a small amount of cleaning is necessary you can sometimes get by with filing the points as shown in Figure 256. File them straight and not at an angle and clean out the housing after filing.

Filing of ignition points is seldom recommended, however, if they are not in too bad condition they can be touched up some and it will improve the operation of the engine.

Figure 257 shows points that are in bad condition and should be replaced. Because of the relatively low cost of ignition points, it is much better to replace them with new ones and be sure you have an engine that operates efficiently.

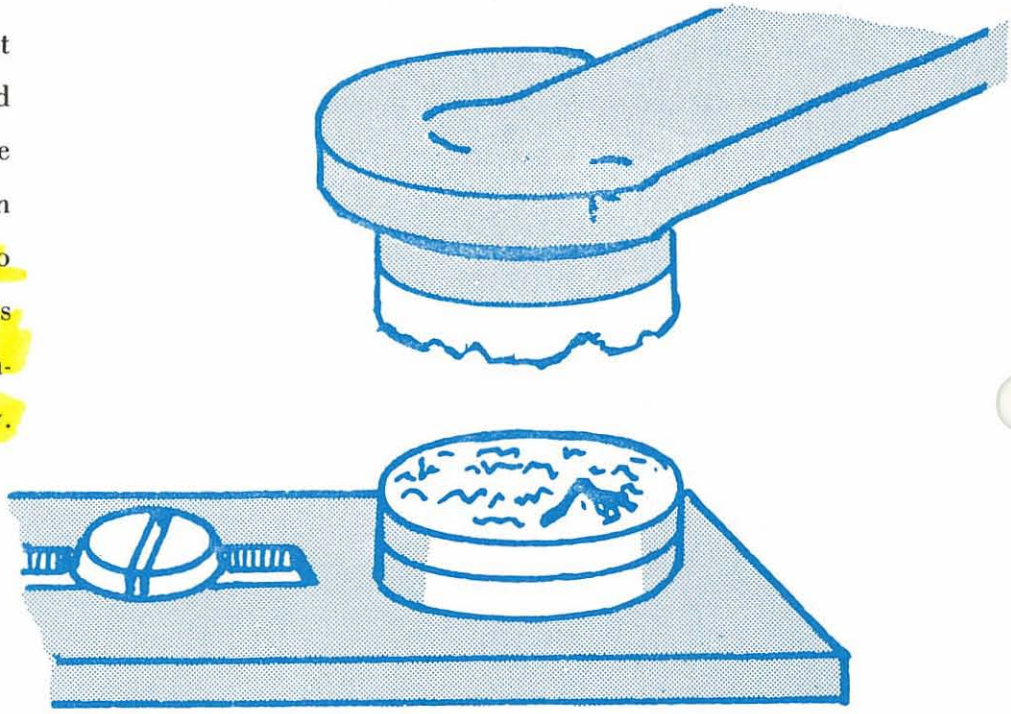
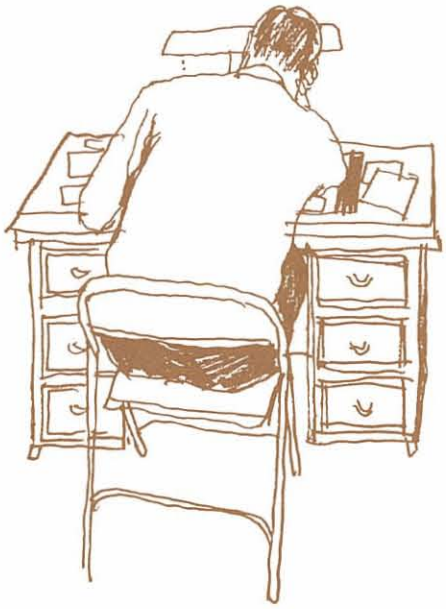


Figure 257

Some points are plated with a high-melting-point material like tungsten, and are so hard they cannot be filed. Always keep points clean and dry when working on them. Do not touch the point surface with your fingers when installing them.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 26
BREAKER POINTS

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NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence fo provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The breaker point spring holds the points together. _____
   TRUE
   FALSE

2. If oil is allowed to get on the contact point, it can ground out the points. _____
   TRUE
   FALSE

3. Contact points must be timed to the rotation of the _____. _____
   a. camshaft
   b. pivot post
   c. crankshaft

4. The cam is directly attached to or part of the crankshaft. _____
   TRUE
   FALSE

5. Filing of the ignition points is recommended if they are in bad condition. _____
   TRUE
   FALSE

6. When the rubbing block is riding on the low part of the cam, the points are open. _____
   TRUE
   FALSE

7. The felt material riding against the cam is used to lubricate the cam. _____
   TRUE
   FALSE

8. The moveable part of a contact point rides on the _____. _____
   a. crankshaft cam
   b. crankshaft gear
   c. camshaft gear

(Continued on page 2)

9. Identify the parts of the breaker point assembly shown in Fig. 26-1.
   cam
   pivot post
   stationary contact block
   rubbing block
   moveable contact point
   breaker point spring

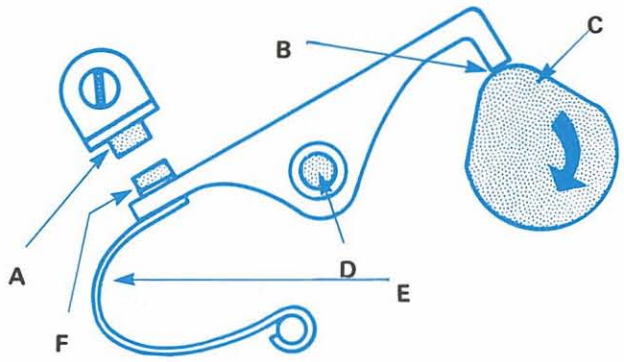

Figure 26-1

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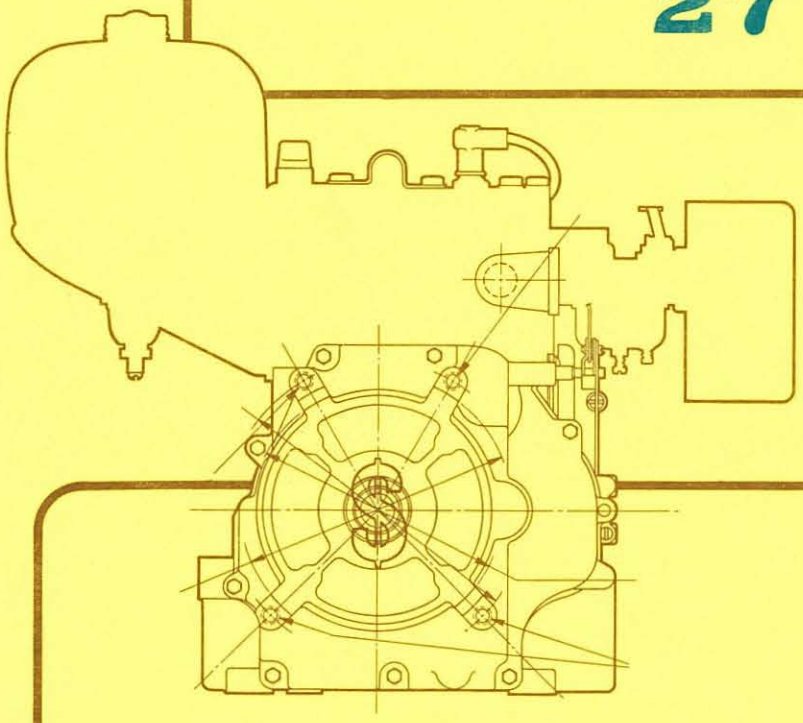
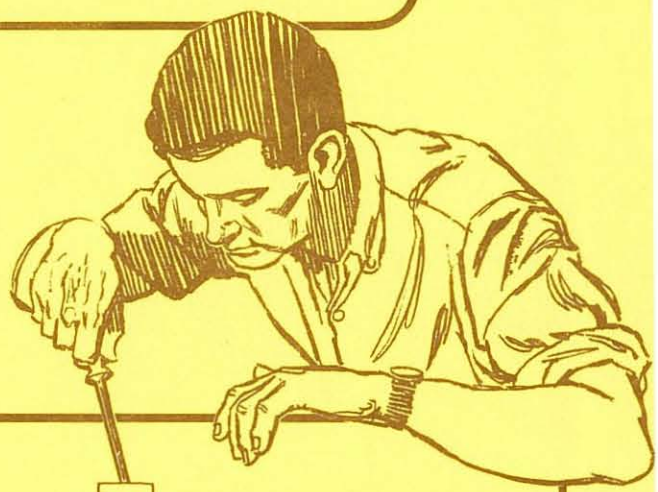
Small Engine

Repair & Service

LESSON NUMBER

27





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...and let's find out all about -- IGNITION SERVICE

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REPLACING POINTS

Figure 258 shows a typical contact point assembly. To replace the points, first set the crankshaft A, as shown, with the contact points open. Remove the nut shown at B and the two wires. One wire C, goes to the condenser and the other wire D goes to the primary lead of the coil. The breaker arm spring shown at E is attached to an insulator. Lift straight up on the insulator and the breaker arm shown at F and remove both pieces. Next, remove the screw shown at G and remove the stationary part of the point assembly.

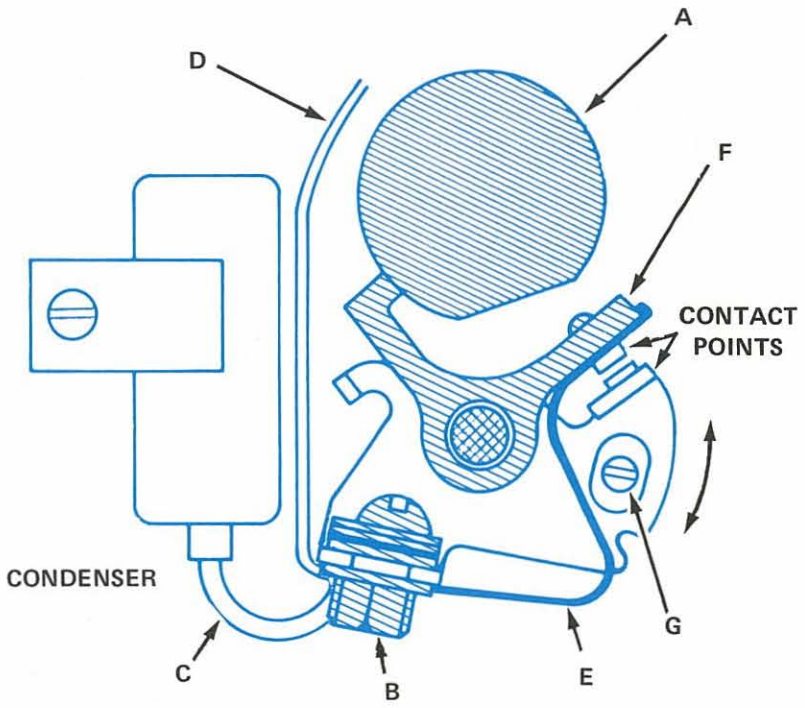


Figure 258

Reinstall the new points the same way the old ones are removed. The contact points should be adjusted to .020 inch. This may vary on some engines but .020 is acceptable for most engines up to about 5 horsepower. Generally the recommended point gap setting recommended by the manufacturer will be given on the dust cover plate or the engine nameplate. Loosen the screw at G and use a feeler gauge to set the gap distance.

Move the adjustable part of the contact points until there is a slight drag on the gauge. Tighten the lock screw G very lightly. Just tight enough so that the adjustment plate and breaker cam will remain in place. Continue tightening the lock screw and rechecking with the feeler gauge. If the adjustment plate tends to creep you can force it a little with the tip of a screwdriver. As you are tightening this screw the plate will have a tendency to open up the contact points as the screw is being tightened because of the rotation of the screw. Continue checking and adjusting as you tighten the screw until you have it firmly locked in place.

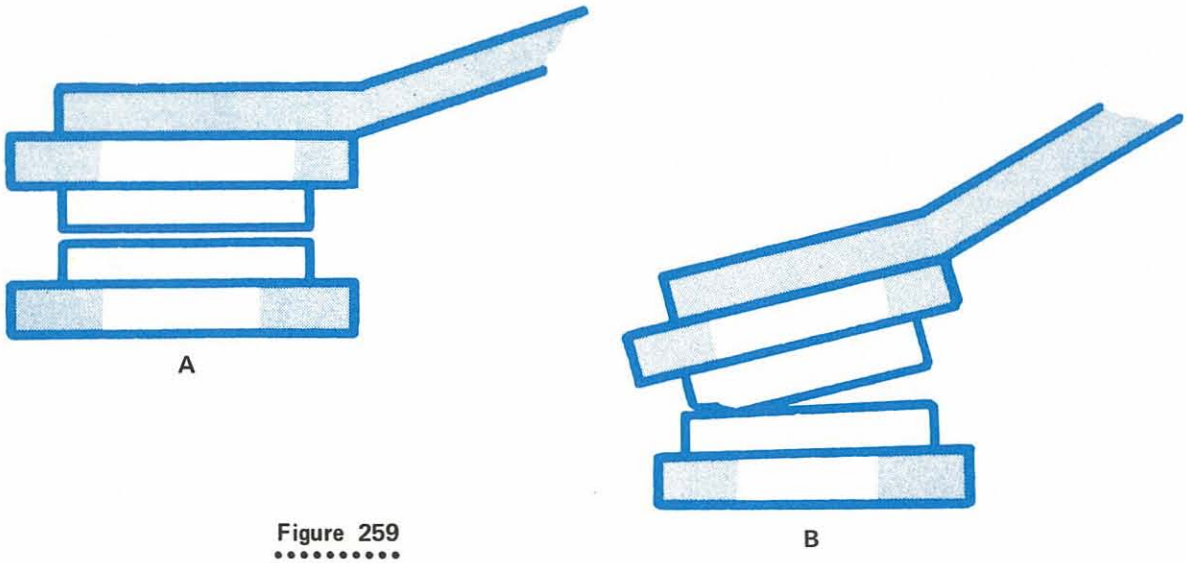
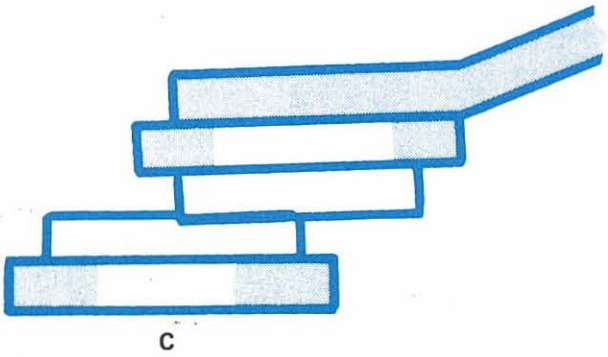
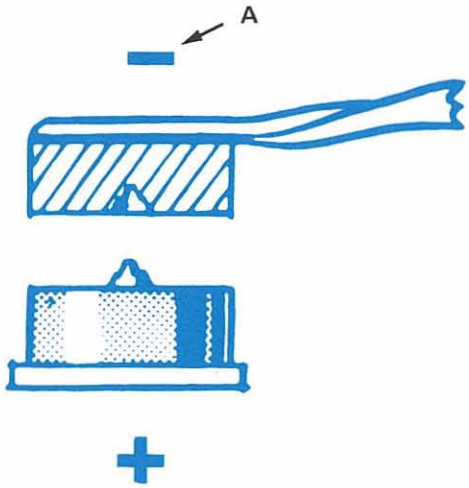


Figure 259



Reinstall the primary lead wire from the coil and the condenser wire and tighten the nut at B. Be sure the points fit together square as shown in Figure 259. The points at A are properly aligned. If they fit as shown at B and C the points will burn, pit and wear unevenly. If they do not fit properly, you can bend the stationary point with a pair of needle nose pliers to make them fit.

After the points are set and tightened, run a strip of paper between the contact points to remove any dirt or moisture. Do not use cloth as it may leave lint. As a last step, always recheck the gap with your feeler gauge before considering the job complete.



CAPACITY
TOO LOW

Figure 260

CHECKING THE CONDENSER

As a general rule you will find it best to replace the condenser every time you change the points. A faulty condenser can burn up a set of points in a very short time. On some points, the condenser is part of the contact point assembly and it is necessary to replace it with the points.

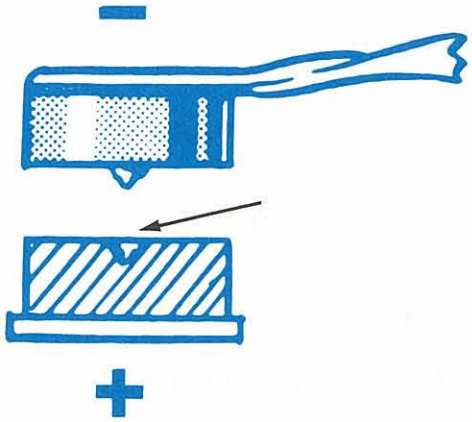
Earlier we studied the construction of the condenser and its function. Some manufacturers recommend changing the condenser every time the points are changed. Others believe the odds of a condenser going bad are so small it would be better to use the old condenser. The recommended procedure among most good shops is to change the condenser each time that the points are changed. Since the cost of the condenser is not a big factor in an engine tune-up, you would be wise to change it every time the points are changed. This is a matter of policy among many shops. Some will check the condenser with a condenser checker.

A condenser checker is an electronic testing machine designed to give you the capacitance rating of the condenser and tell you if the condenser is open or shorted. A condenser is rated in units called "microfarads". This is abbreviated as "MFD". The larger the capacity in MFD, the more current it can store and the more time is required to charge it to capacity. As mentioned before, the purpose of the condenser is to store current for a short time to avoid letting excessive voltage go across the points and arcing them. It is very important that the condenser be of the proper capacity for the application it is used for. A condenser of improper capacity will be indicated by the condition of the contact points. If there is a pit or hole in the contact points that matches another pit or hole on the other point as shown in Figure 260, the capacity of the condenser is too low. The negative side, shown at A, would be the grounded side of the contact points. This would be the adjustable side of the contact points.

The pit or hole effect is caused by the transfer of metal from one contact point to the other. The direction in which the metal transfers indicates the remedy. Figure 261 shows the effect when the capacity is too high. Instead of the pit being on the negative side of the points it will be on the positive side. This is the moveable side of the contact points, the one that works on the crankshaft.

Some points are attached to the condenser and it is necessary to replace it when replacing the points. This forces the replacement of the condenser each time the points are changed and will, very possibly, be a design change going into many other small engines in a short time.

The average range of condensers used on most small engines will run from 15 to 25 MFD. If you will make it a practice to always replace the condenser along with the contact points you can save a lot of time and trouble-shooting if the engine does not function properly after tune-up. Condensers can sometimes be erratic and show a proper test reading but not function properly under load.



CAPACITY TOO HIGH

Figure 261

CHECKING MAGNETO COILS

Magneto coils seldom give trouble. You should always make a complete check of the rest of the system before deciding to replace a coil. A weak spark, or no spark could be due to a damaged or defective coil and it can be tested without removing it from the magneto. First inspect for obvious damage such as short or broken wires or evidence of overheating. There are special coil testers available, however, you can make a simple one from a 6-volt battery, two lead wires and alligator clips as shown in Figure 262.

Use a regular 6-volt lantern battery as the power source. Solder one wire lead about three feet long to the center battery terminal shown at A and attach an alligator clip to the other end as shown at B. Be sure to keep these lead clips apart or they will short out the battery.

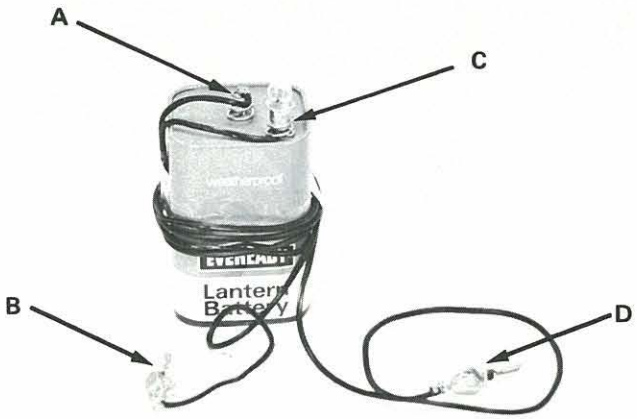


Figure 262

Use another short piece of bell wire about three feet long and solder one end to the center terminal of a 6-volt lantern bulb, shown at C. By clipping off about two turns of the spring type battery terminal you can thread the lantern bulb into the spring. Attach an alligator clip to the other end, as shown at D. Wrap tape around the two wires and the battery to hold the wires in place. This tester makes a very satisfactory piece of equipment for testing coils and for continuity testing.

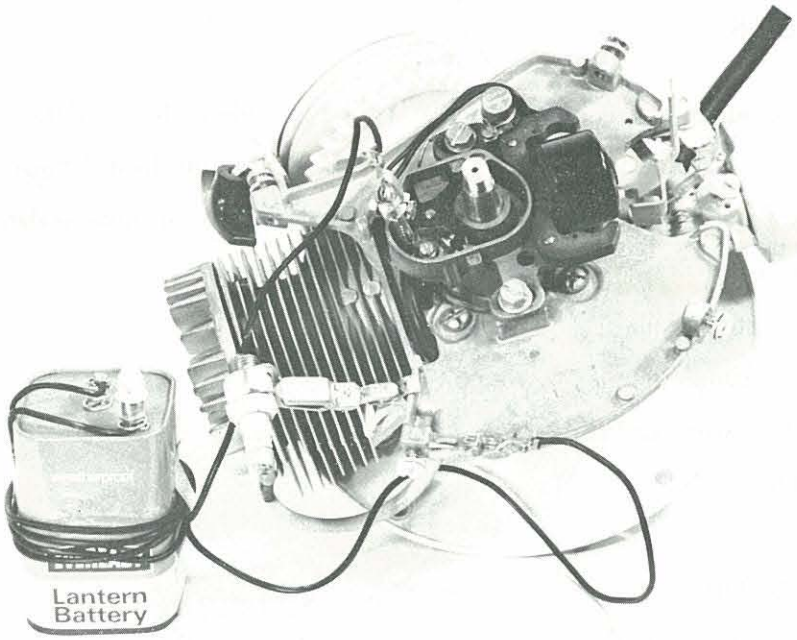


Figure 263

To get a good coil test it would be a good idea to use the test spark plug shown in Figure 263. Connect the test plug as shown with the high tension lead of the coil attached to the spark plug and ground the outside of the plug to the engine frame as shown.

Turn the crankshaft until the points are fully open. Attach one clip of the tester to the engine frame. Next, touch the other clip of the tester to the spring part of the contact point. Touch it just momentarily. Do not hold it in place long, just a short prod or a couple seconds. The spark will be most intense when you touch the prod to the insulated spring of the points for a second and release it quickly to break the contact.

This is the same action as when the engine is running. What you are actually doing is energizing the primary circuit and building up a magnetic field in the coil. When you break the circuit, by suddenly removing the prod, the primary field collapses. This induces a high voltage in the secondary field and provides a spark at the spark plug.

If you get a good spark at the plug when you scratch the prod on the insulated breaker point, with the points open, both the primary and the secondary circuit should be functioning properly.

If you do not get a good spark at the plug, do not conclude the coil is bad without first checking to see if all wires and connections are tight and in good condition. These tests are generally good enough to tell if the coil is good or bad. The only true way is with a regular coil tester.

Do not use a coil tester on a metal workbench. There is danger of being shocked by the high voltage from the secondary coil that can be carried off by the metal bench.

STATOR PLATE AND COIL SERVICE

Figure 264 shows the stator plate and coil assembly attached to the ignition housing. Before removing the ignition housing, shown at A, be sure to check for the timing marks, shown at B. If the engine does not have these timing marks, use a sharp punch or chisel to make these identification marks on both the ignition housing and the engine housing. Make identification marks on both sides so you can replace the ignition housing exactly as it was before removing it.

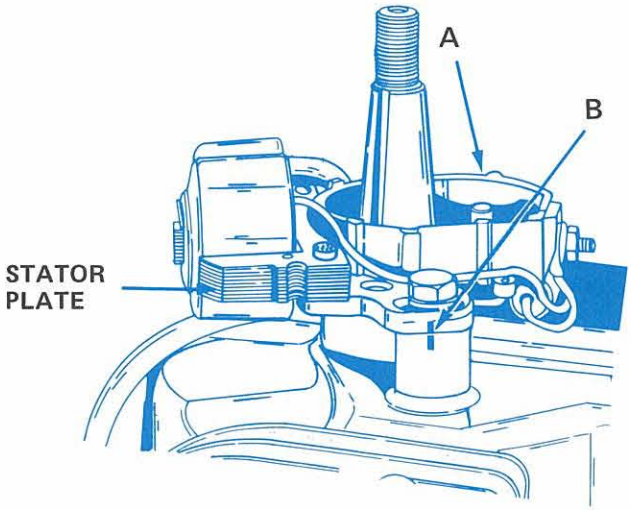


Figure 264

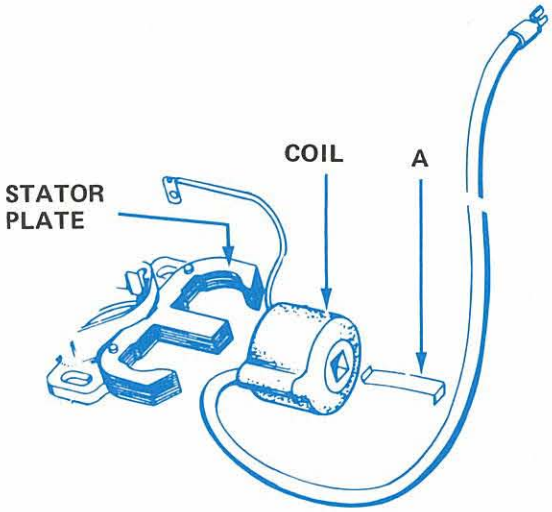


Figure 265

If the coil check shows it to be defective, it can easily be replaced. Figure 265 shows the coil assembly. Most coils can be removed from the stator plates by removing the lock tab shown at A. This tab can be pulled straight out. It's generally made of a spring steel with a slight bend so it will cause a wedging action between the coil and the stator plate. This holds the coil to the stator plate.

Sometimes the coil is attached to the stator plate with an epoxy glue. If so, place the engine securely in a vise. Then, as shown in Figure 266, use two screwdrivers to lift up on both sides at the same time.

When replacing a coil be sure to replace the lock tab on the same side it was removed from. If installed wrong it may interfere with other functions on some engines.

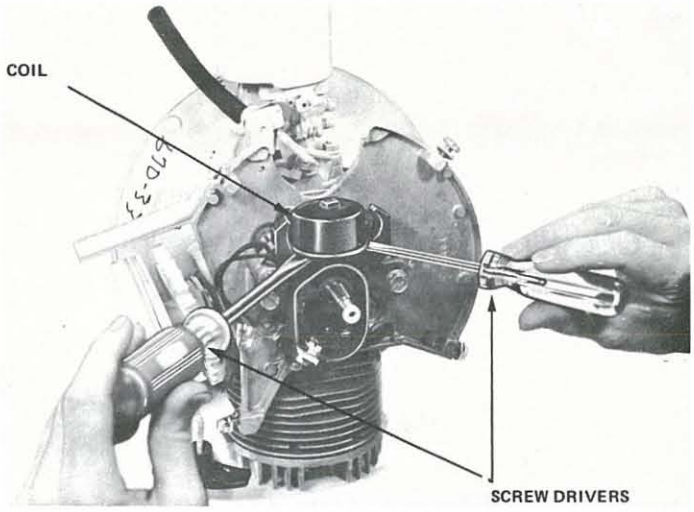


Figure 266

Some magneto stator plate assemblies do not have provisions for adjustment. They are factory adjusted or only have provisions for air gap adjustment which we will cover later. Figure 267 shows the basic types of stator plates used on many small engines. The one shown at A has no provisions for adjustment. The one at B has provisions for vertical adjustment only. This is an in and out adjustment for the air gap. It has no effect on the timing. The one shown at C is for rotational timing adjustment and air gap adjustment.

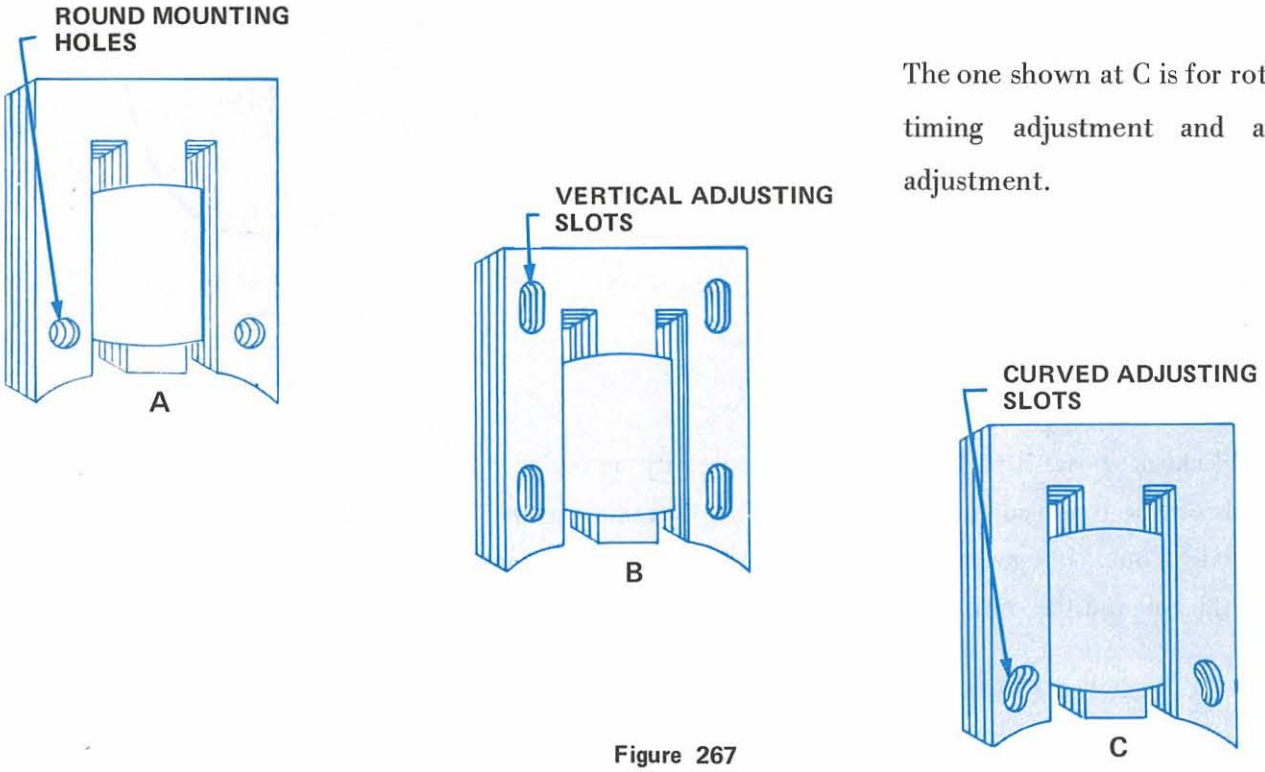
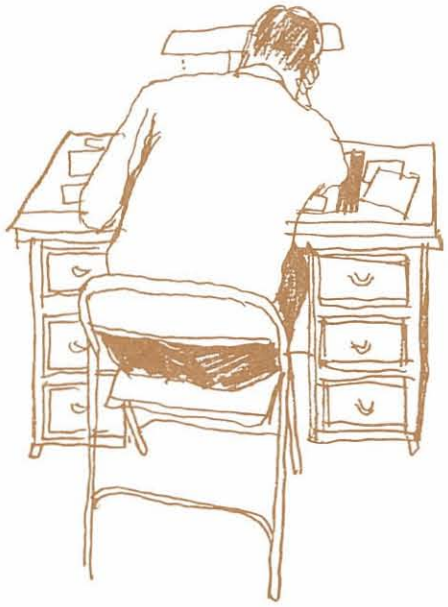


Figure 267



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(FILL IN)

(Leave Blank) GRADE(s)_____ _____

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- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Condensors used on most small engines will run from _____ to _____ MFD. _____
   a. 5 to 10
   b. 10 to 15
   c. 10 to 25
   d. 15 to 25

2. As a general rule, you will find it best to change the condenser every time you change the points. _____
   TRUE
   FALSE

3. Before removing the stator plate and coil from the ignition housing, be sure to check for _____. _____
   a. dust and dirt
   b. timing marks
   c. primary lead

4. To replace the points, first set the crankshaft so that the points are closed. _____
   TRUE
   FALSE

5. Magneto coils are a common source of trouble. _____
   TRUE
   FALSE

6. A faulty condenser can cause the points to burn. _____
   TRUE
   FALSE

7. A condenser is rated in units called _____. _____
   a. volts
   b. microfarads
   c. amperes

8. The contact points should be adjusted to _____ for most small engines. _____
   a. .010″
   b. .015″
   c. .020″
   d. .025″

(Continued on page 2)

9. If there is a pit or hole in the points that matches another pit or hole on the other point, the _____ of the condenser is too low. _____
   a. amperes
   b. capacity
   c. volts
   d. microfarads

10. Condensers showing a proper test reading will always function properly when under load. _____
    TRUE
    FALSE

11. A condenser checker will give you the capacitance rating and tell if the condenser is open or shorted. _____
    TRUE
    FALSE

12. Some magneto stator plate assemblies do not have provisions for adjustment. _____
    TRUE
    FALSE

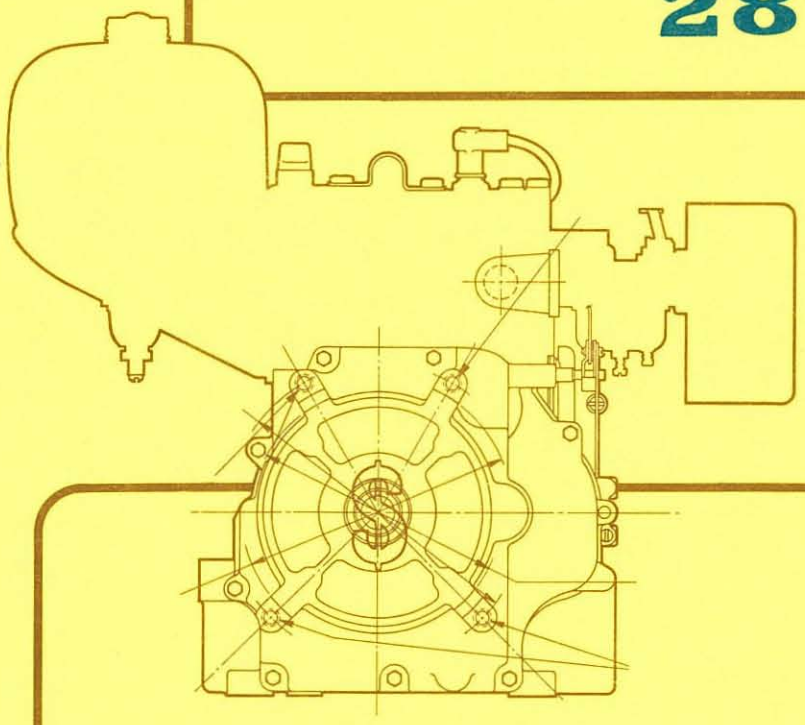
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

28



TURN THIS PAGE

...and let's find out all about -- **MAGNETO TIMING**

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TIMING MAGNETO TO THE ENGINE

Timing of the magneto is seldom necessary. If the spark plug and breaker points are in good condition, check the timing. The bolts holding the stator plate or housing could have become loose allowing this unit to shift. Sometimes an engine owner will attempt repairs and remove or shift the location of the stator plate which will change the timing.

Timing the magneto to the engine consists of adjusting the stator plate assembly. The stator plate assembly includes the coil and the laminated yoke as shown in Figure 265. The center line of the rotating magnet should be just past the center line of the stator plate when the piston is at the desired position for ignition to take place. This will be on or before the piston reaches top dead center on the compression stroke.

On most 2 and 4-cycle small engines the ignition firing will be about 1/16-inch before the piston reaches top dead center (B.T.D.C.). To accomplish this the factory designs the flywheel keyway, the magnet location and the stator plate assembly so they will be in the proper place to give the greatest spark when the points are open.

As we mentioned earlier, the stator plate assembly, shown in Figure 267A and B has no provisions for timing adjustment. If the timing is not correct on engines using this type magneto, it is very possible that the flywheel key is loose or partially sheared. If the magneto has curved slots for adjustment, first locate and check the timing slot marks. In addition to being located as shown in Figure 264, they could also be on the flywheel or the flywheel housing.

When the engine has no timing marks visible, or they cannot be located, it will be necessary to find the timing setting by working back from the piston with it setting on TDC or BTDC (Before top dead center).

First remove the spark plug. Then set the breaker point gap, using the same procedure we covered earlier.

Top dead center (TDC) is the point when the piston reaches the top of its stroke when it is making the compression stroke. You can easily tell when the piston is in the compression stroke. Every UP stroke of a 2-cycle engine is a compression stroke. Every second UP stroke of a 4-cycle engine is a compression stroke. The alternate UP stroke is the exhaust stroke since the exhaust valve is open. On the compression stroke of a 4-cycle engine both valves are closed. You can tell which is the exhaust stroke by placing your finger over the spark plug hole. As the piston reaches the top of the cylinder on the exhaust stroke, the air that is compressed in the cylinder escapes through the exhaust valve. On the compression stroke, both valves are closed and you will feel air being forced against your finger.

When the piston is at TDC it will be in the position shown in Figure 268 with the piston moving up as shown by the arrows. This is the maximum distance the piston can travel in the UP direction. This is not the firing position, although in the study of the basic principles of engine operation it is generally shown at top dead center when the spark occurs.

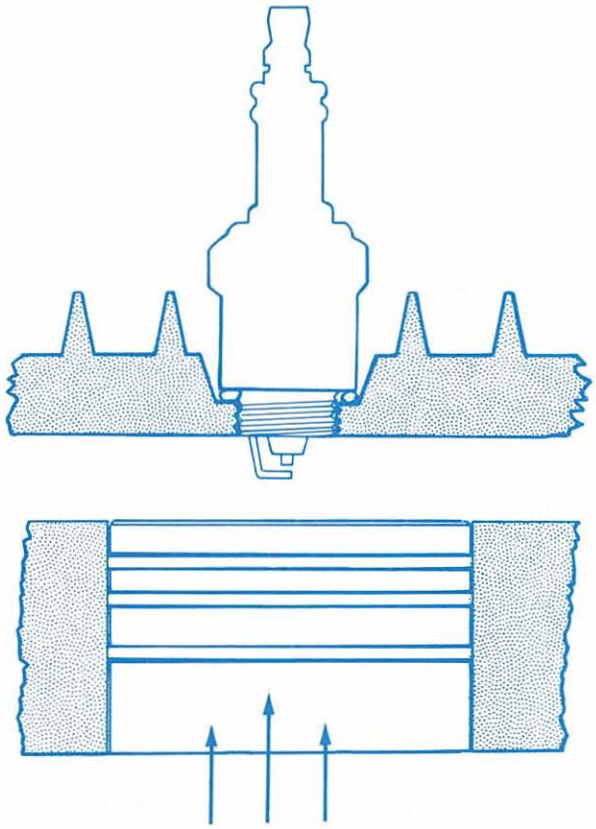


Figure 268

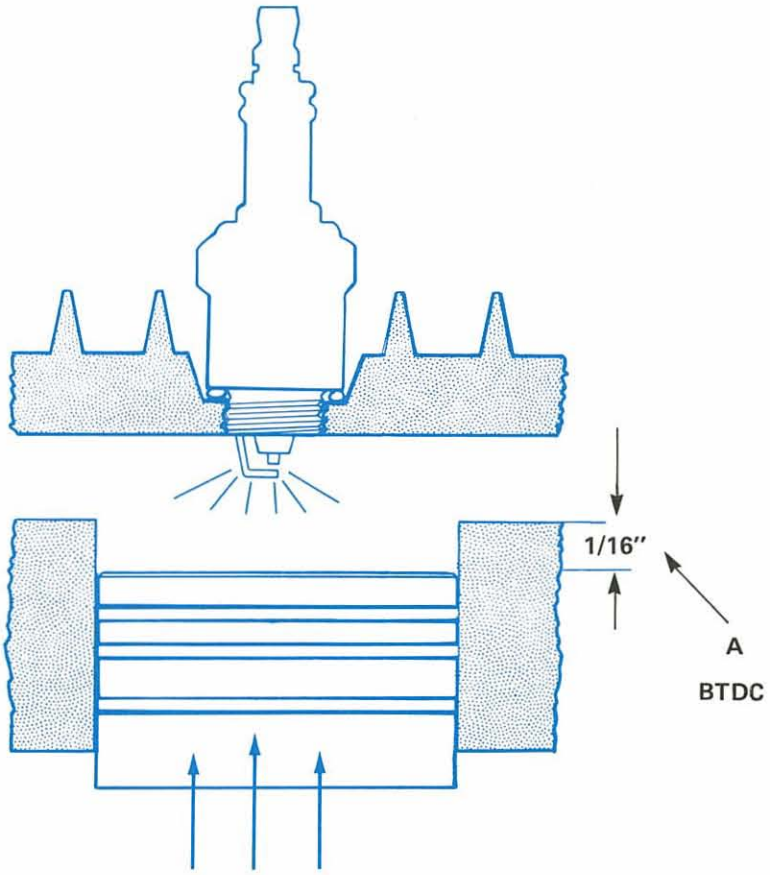


Figure 269

Figure 269 shows the piston going up and the spark plug firing just before the piston reaches TDC. The distance of 1/16-inch, shown at A, is the position the piston would be in when the plug fires. This is 1/16-inch BTDC.

To find TDC, first bring the piston up on the compression stroke for 4-cycle engines and on the up stroke for 2-cycle engines. Use a small steel rule calibrated in 1/32 or 1/16 inch markings. Insert it in the spark plug hole against the top of the piston. As the piston comes up the rule will begin moving out of the spark plug hole. When the piston hits TDC the rule will not move. After the piston reaches TDC the rule will begin to go down. Turning the crankshaft the opposite direction the rule will begin to come up again.

After you find TDC, lay a straight edge across the top of the head as shown in Figure 270 at A, and take a measurement with a steel rule at point B. This reading will be exact TDC. Suppose this reading was 1-inch, you would then add 1/16 and come up with 1-1/16 inches.

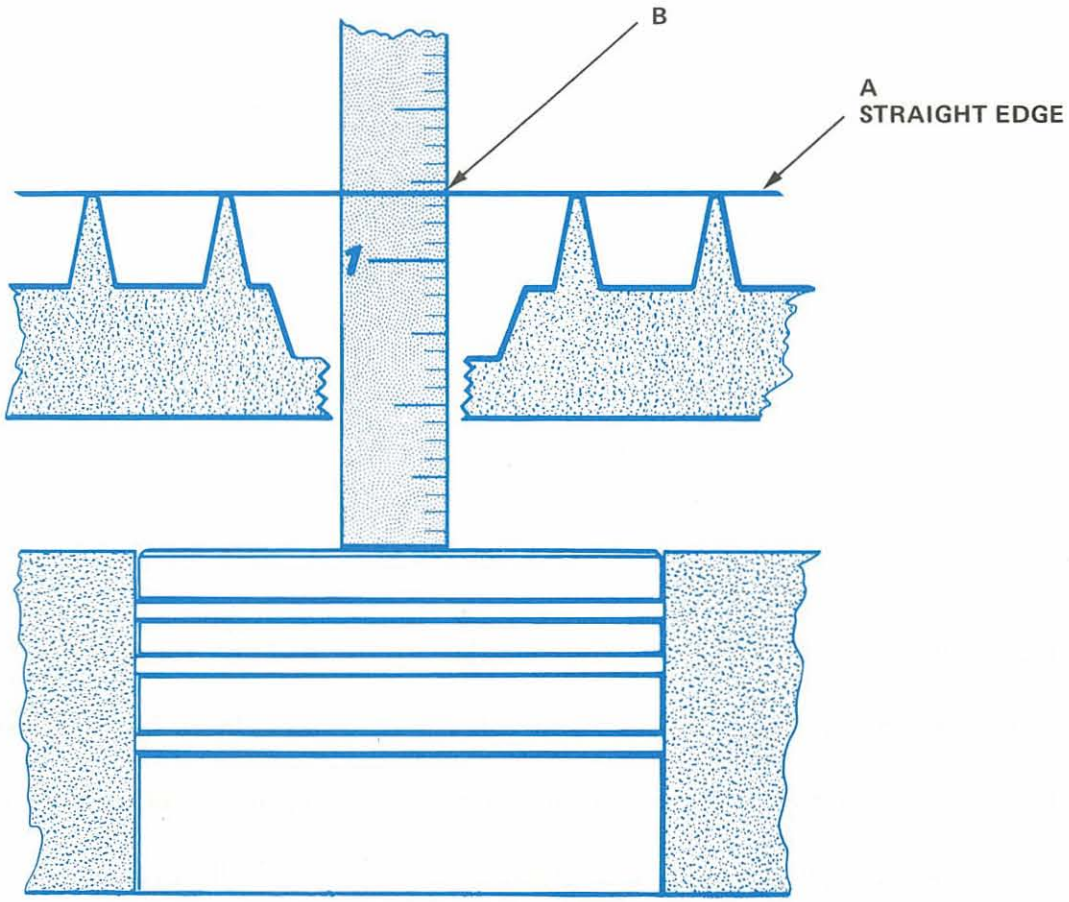


Figure 270

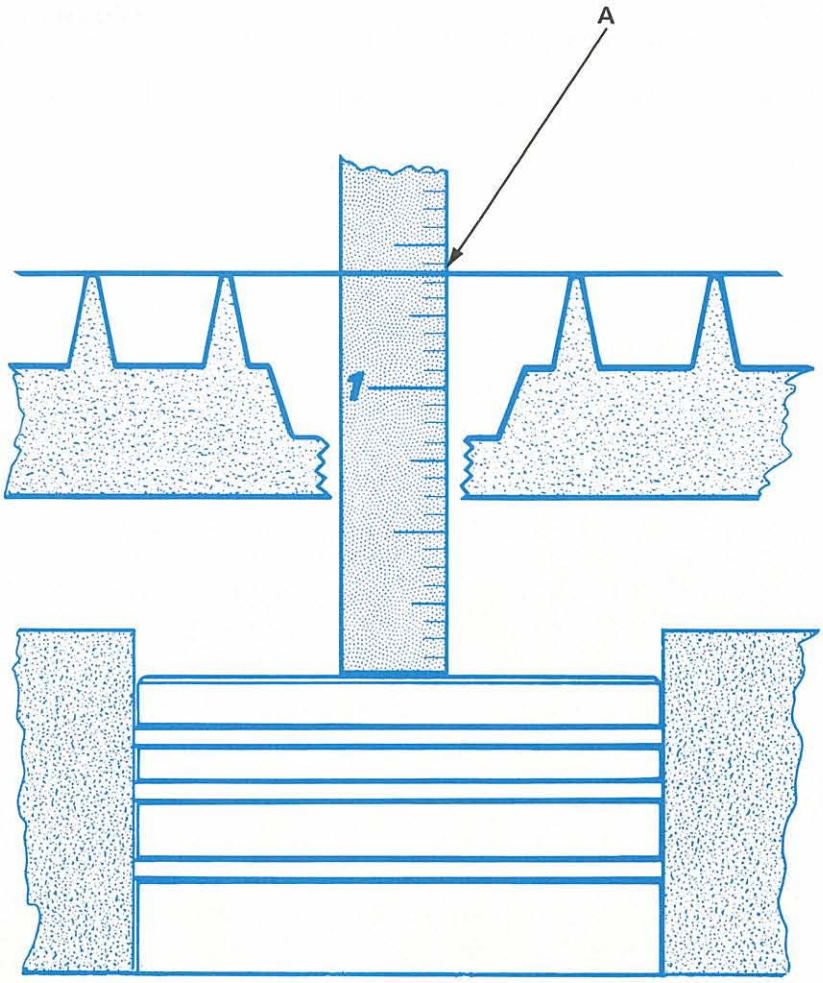


Figure 271

Drop the piston back down until you get a reading of 1-1/16-inch. When dropping the piston back down be sure to turn it so this measurement is BTDC and not after top dead center. Lower the piston as shown in Figure 271 until the reading at A shows 1-1/16-inch. This is the position of the piston when it is 1/16-inch before top dead center.

After you have the piston in the proper position, BTDC, you can begin to adjust the stator plate so the contact points just start to open. One way way to get an accurate reading of the points when making this adjustment is to use the same continuity light used to test the coil.

Attach one lead of the test light to the ground or engine frame as shown at A in Figure 272. Attach the other lead to the terminal of the moveable part of the breaker assembly as shown at B. Before attaching the test lead wire to this terminal remove the condenser and ground wire shown at C and D, otherwise it will ground out the circuit.

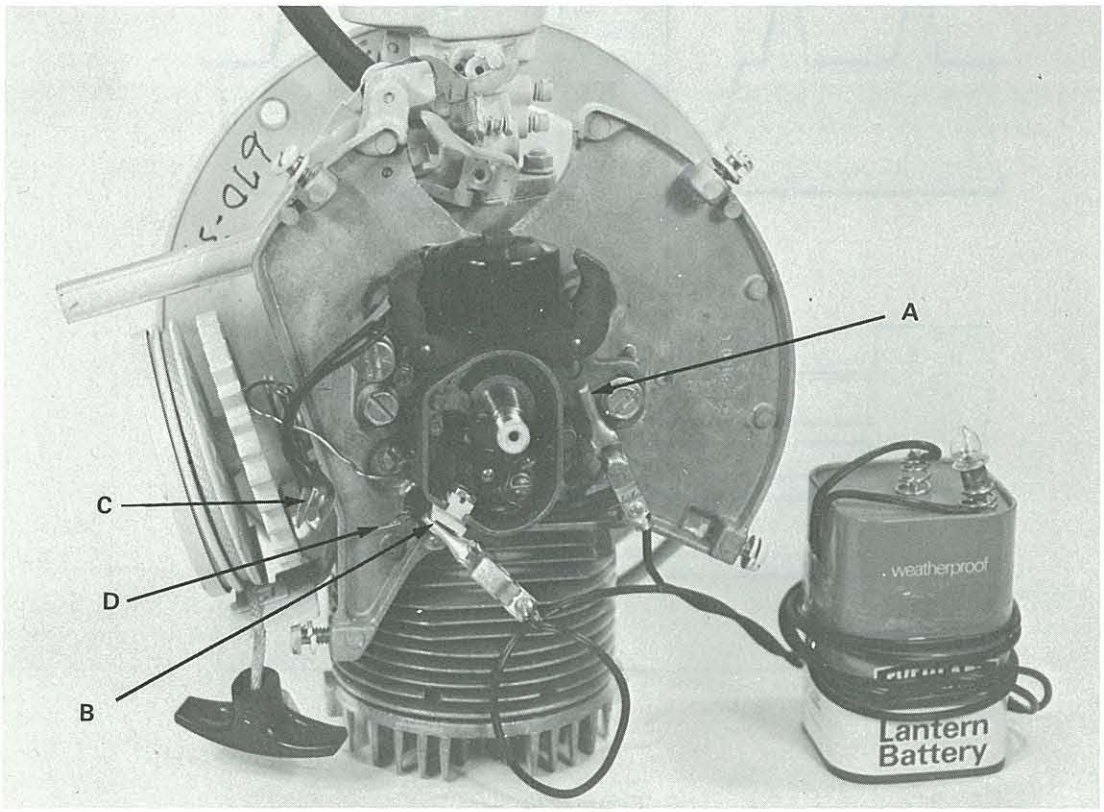


Figure 272

After you have the test wires attached as shown in Figure 272, you can begin adjusting the stator plate. First loosen both bolts holding the stator plate to the housing. Rotate the stator plate back and forth until the points just start to open. The light will be on when the points are closed, but will go out just as soon as the points start to open. When the points start to open and the light goes out, stop adjusting the stator plate and tighten both bolts holding it to the frame. The magneto is now timed to the engine. Recheck and adjust the contact points if necessary.

TOP DEAD CENTER TIMING TOOL

There is a tool available at most automotive supply houses that is used to find the TDC. This tool makes it much easier than using the steel rule we covered earlier. Figure 273 shows a typical TDC finding tool. The bottom part of the body, shown at A, is threaded to fit the spark plug hole. There is a calibrated gauge shown at B that slides inside the body.

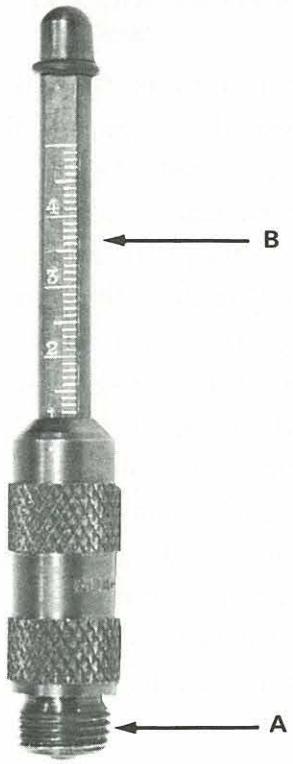


Figure 273

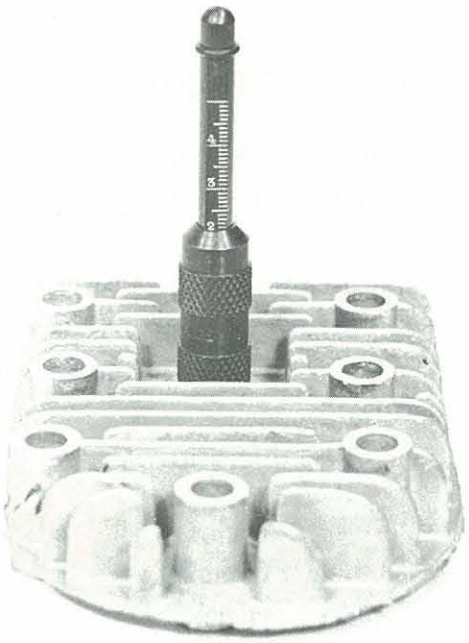


Figure 274

Figure 274 shows this tool installed in the spark plug hole. As the piston moves up and down the gauge will move the same amount since the end rides on the top of the piston. As the piston reaches TDC the gauge will stop. As the piston begins to go down the gauge will go down. Find TDC the same as with the steel rule and then drop the piston back 1/16-inch by reading directly on the scale of the gauge.

ARMATURE AIR GAP

The armature air gap is the space between the laminated iron cores or the yoke and the rotating magnets. Figure 275 shows the armature air gap. It is the distance shown at A. The stator plates, shown at B, have adjusting slots that allow them to be moved closer or away from the flywheel. The distance between the flywheel stator plates and the flywheel magnets is the air gap. The closer the spacing of this air gap, the stronger the spark produced. Some magnetos do not have provisions for adjusting the air gap. Those without air gap adjustment provisions can get out of adjustment by a worn crankshaft bearing or bent crankshaft.

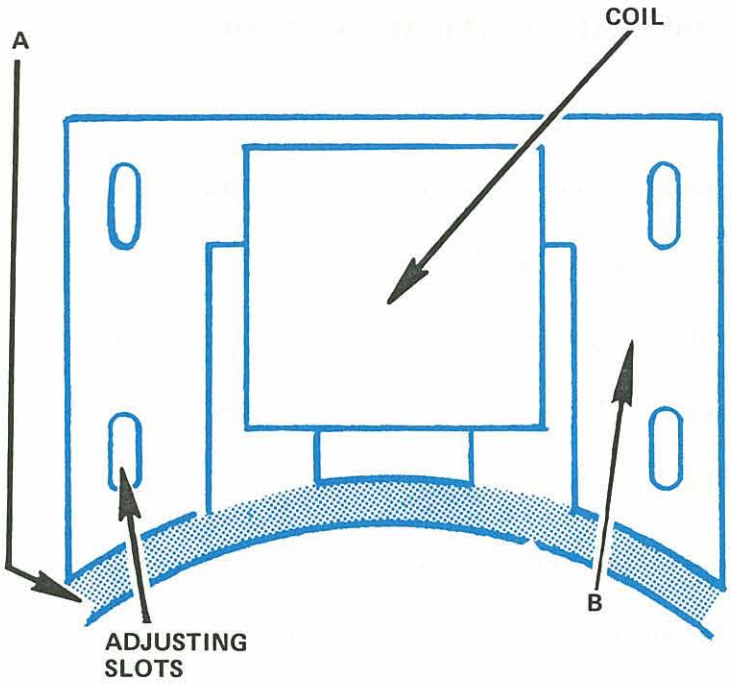


Figure 275

Most of the small engines used on lawnmowers and other similar applications do not have provisions for adjusting the air gap because they do not have adjustable stator plates and are located under the flywheel. On outside mounted armatures, as shown in Figure 275, they are generally made adjustable. An air gap of about .0075-inch is generally acceptable.

Figure 276

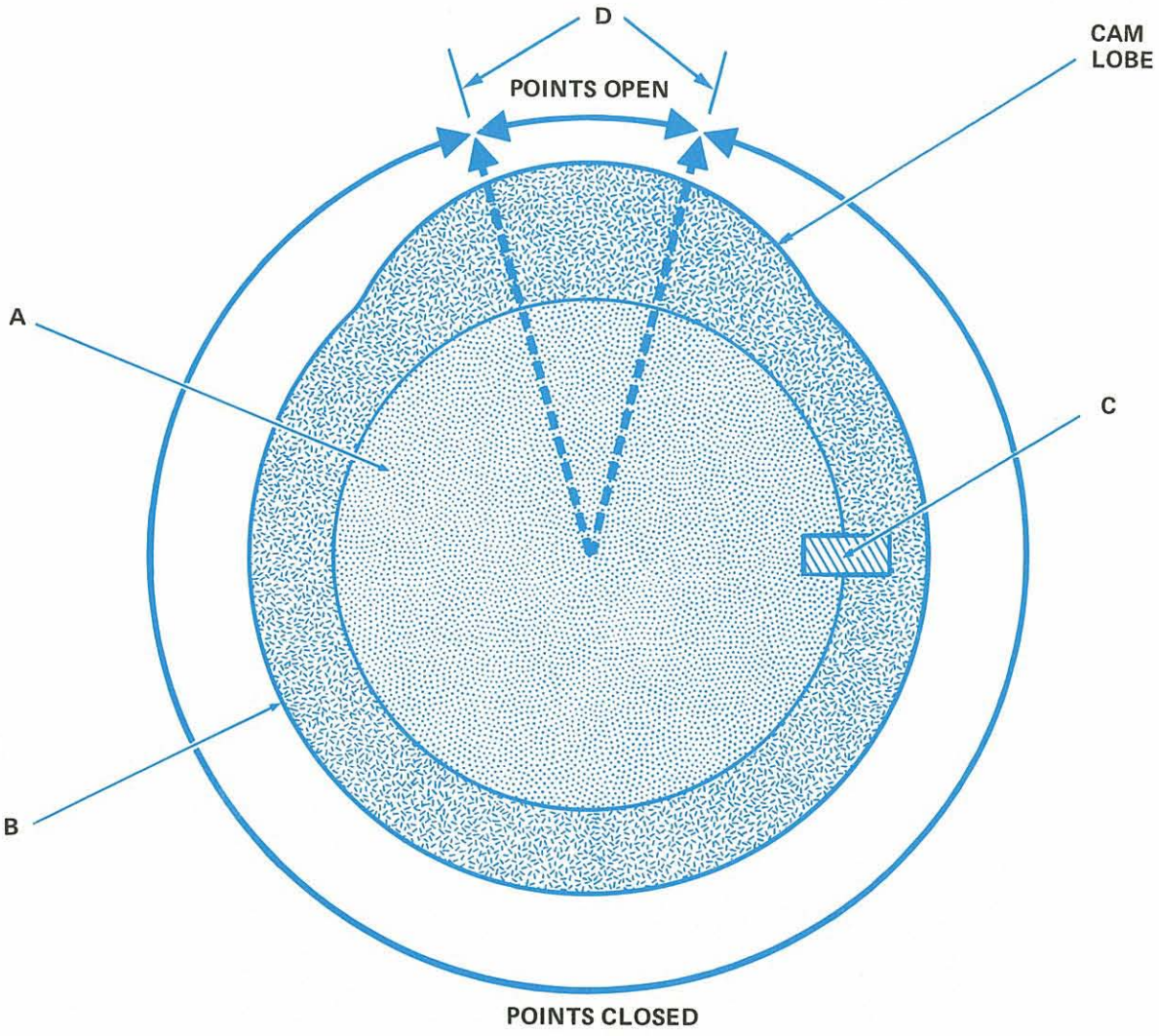
MAGNET STRENGTH

A test to determine the strength of the magnetic field of the flywheel is shown in Figure 276. Lay the flywheel on a bench as shown and hold a screwdriver above the two magnets as shown. You should feel a definite pulling action and the magnet should pull the screwdriver sideways as it is moved across the top of the magnetic field.

Most small engines now use Alnico magnets and they cannot be recharged. Some small engines have provisions for replacing the magnets while others have them built into the flywheel and require replacement of the flywheel.

BREAKER POINT AND CAM FUNCTIONS

The breaker points must be adjusted properly. If the points are set too close they will retard or slow the timing because the cam must move farther to open the points. This causes the spark to occur late and the piston passes the point where most effective ignition should occur.



POINT GAP SET TOO CLOSE

Figure 277

Figure 277 shows a cross section view of the crankshaft, keyway and the cam. The crankshaft, shown at A, is held to the cam B with the key shown at C. The distance shown at D is the area where the points are open when the point gap is set too close. If the distance shown at D were measured to be 40 degrees it would mean the points would be closed for 320 degrees of each complete turn. Since the opening point on the cam must travel 320 degrees it will cause the spark to occur late.

Figure 278 shows what happens when the points are set too close and the spark occurs late. The spark should occur when the piston is at BTDC as shown at A. When the points are set too close ignition will occur when the piston is in the position shown at B. It is above or past the BTDC. This will cause the engine to lose power as the piston has passed the point where the most effective ignition should occur. Ignition should have occurred at A.

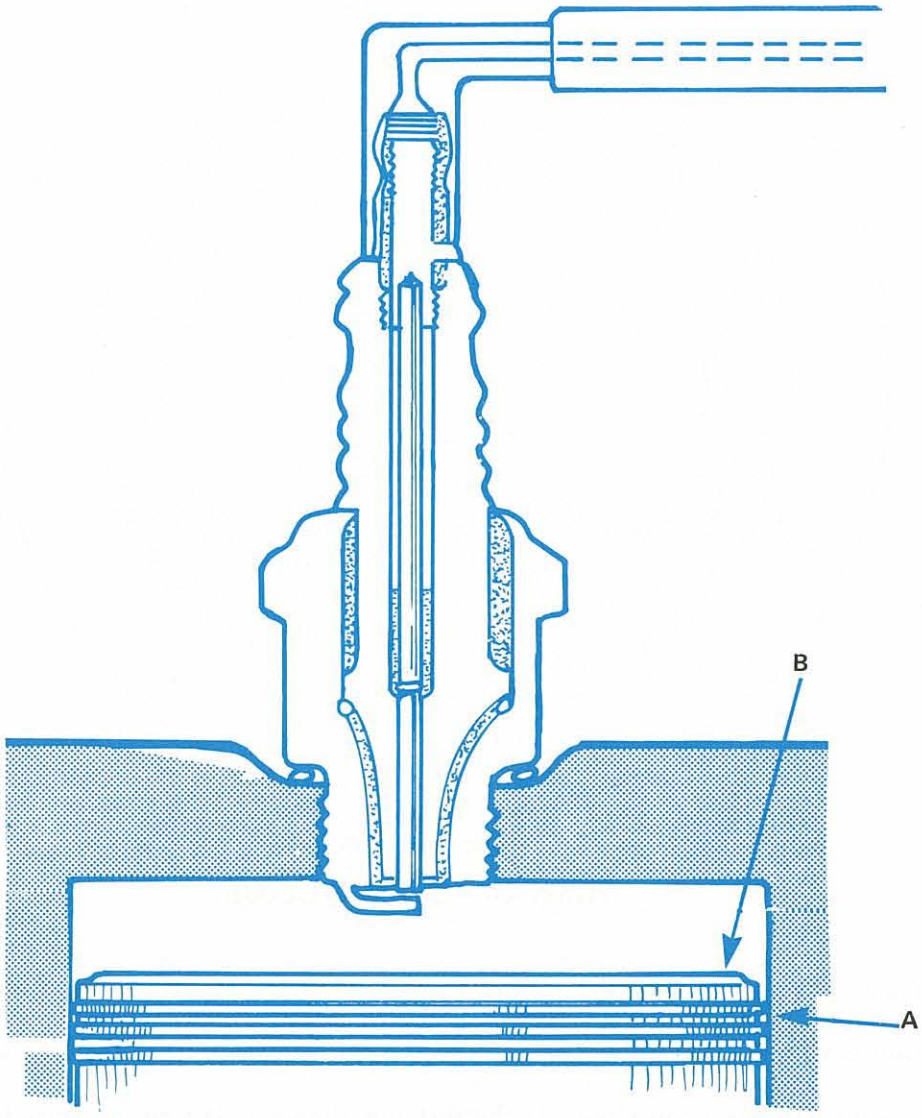
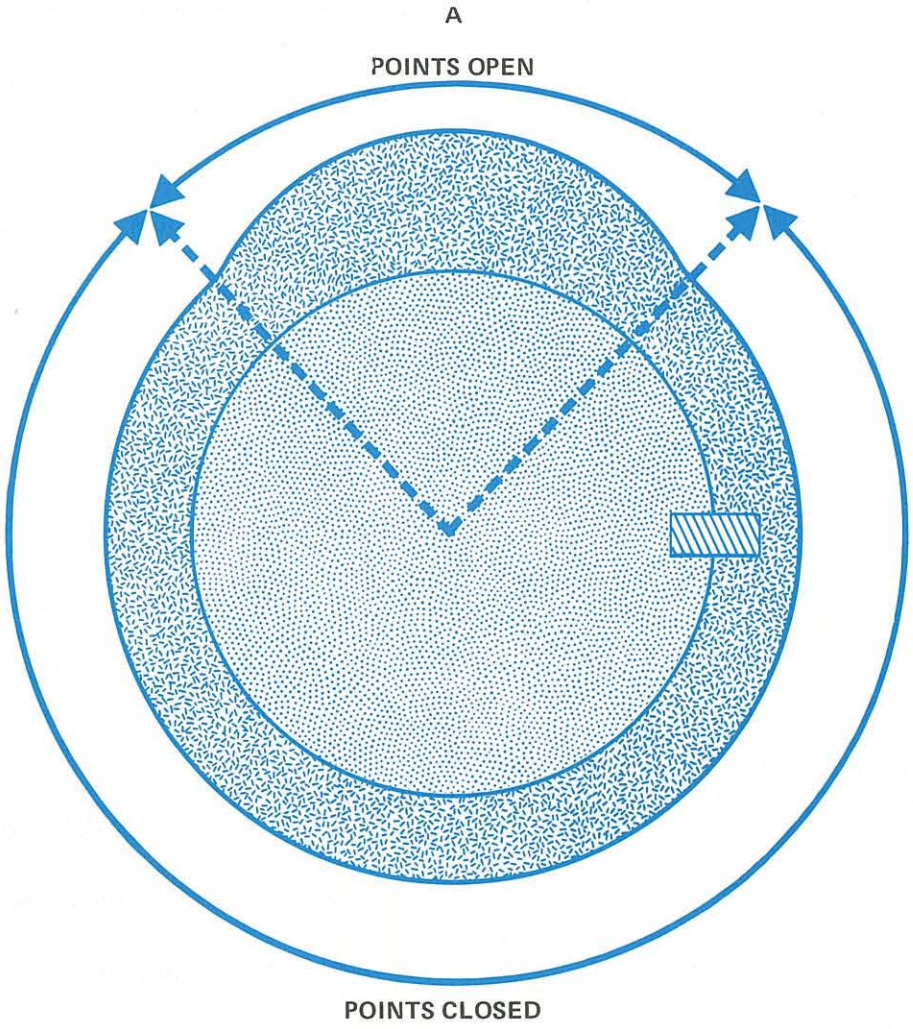


Figure 278

When the points are set too far apart, it will cause the spark to occur too soon. Figure 279 shows what happens when the points are set too far apart and the spark occurs early. If the points were open in the area shown at A, they would be closed during the rest of the rotation. If this angle were 90 degrees, it would mean the points were closed the other 270 degrees. It would take a rotation of 270 degrees for the cam to return to the position where it would start opening the points again.



POINT GAP SET TOO FAR APART

Figure 279

Figure 280 shows what happens when the points are set too far apart. The BTDC firing point is shown at A. This is the position the piston should be in for most effective ignition. With the points set too far apart, ignition would occur when the piston is in the position shown at B. This would cause the ignition to occur before the piston reaches the position to create maximum desired compression of the fuel-air mixture. This will cause the engine to lose power. It also causes the engine to kick backwards when cranked.

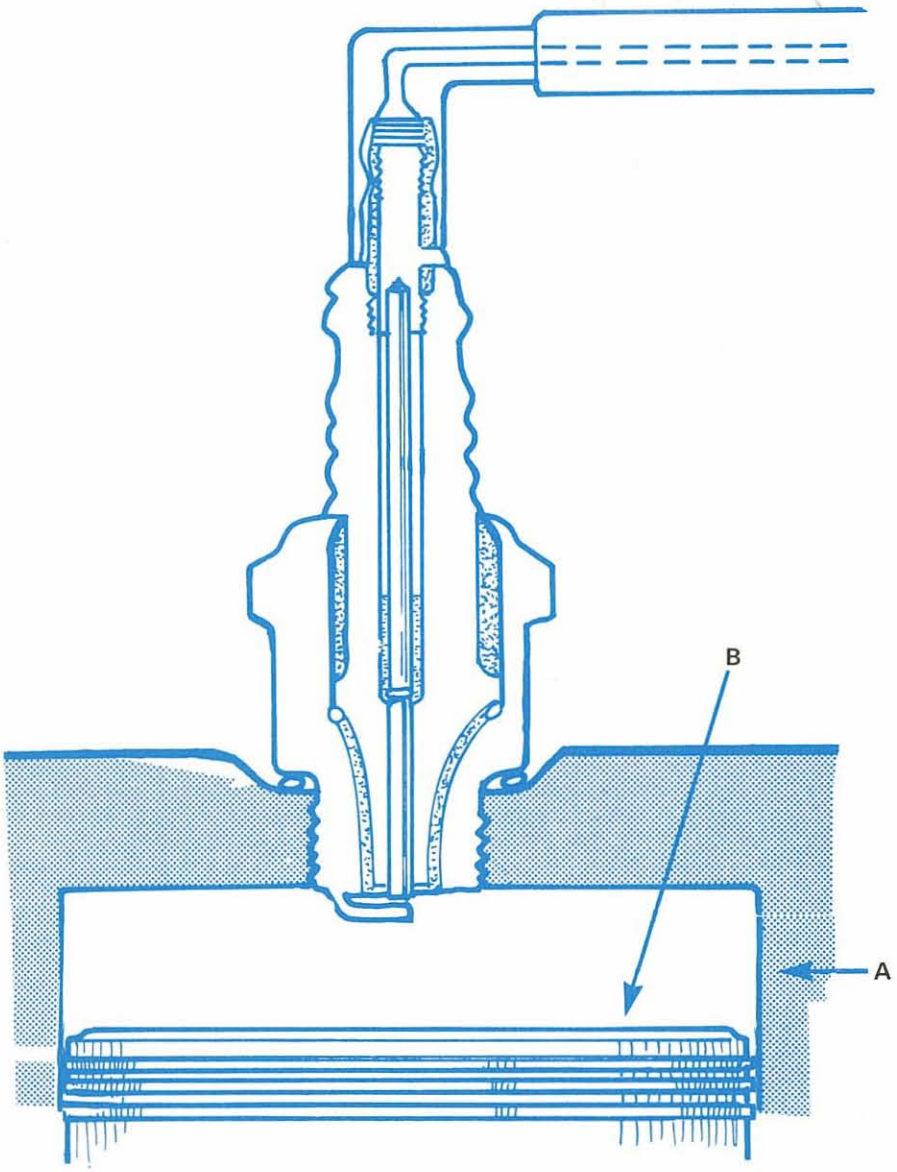


Figure 280

If the points are set either too far apart or too close together, it will cause the spark to occur either before or after the desired time for maximum combustion and when the magnetic field is at its highest intensity. Continued operation with the ignition system out of order will result in overheating, valve burning and other complications

BATTERY IGNITION SYSTEMS

The battery ignition system is similar to the magneto system we have been studying. Current is supplied from the battery instead of the magneto but it is low voltage current. Earlier we studied the principles of the coil and how it could convert low voltage to high voltage. The battery ignition system also uses a coil.

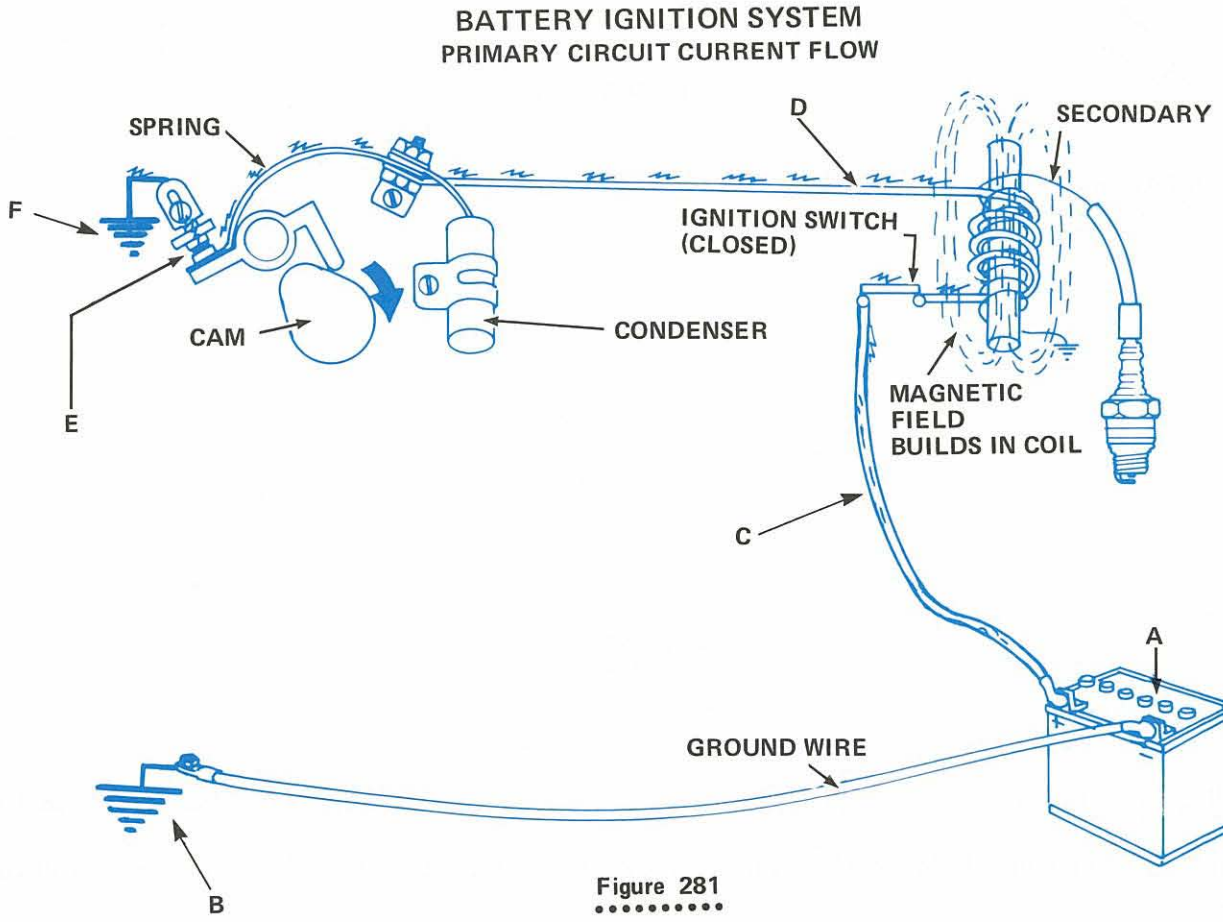


Figure 281

Figure 281 shows the primary circuit of the basic battery ignition system. Current is supplied by the battery shown at A. This is usually a six or twelve volt system. The negative terminal of the battery is grounded at B. This is usually to the frame of the engine which acts as a ground for the entire electrical system.

The positive battery cable at C, goes to the ignition switch which is closed. From there it goes through the primary circuit of the coil shown at D, and to the contact points E. It then goes through the contact points since they are in the closed position. From there it goes back to ground at F. This is low voltage going direct to the points. There is no ignition at the spark plug. The circuit is through the battery, primary circuit of the coil, ignition points and back to ground.

BATTERY IGNITION SYSTEM (CON'T)
SECONDARY CIRCUIT CURRENT FLOW

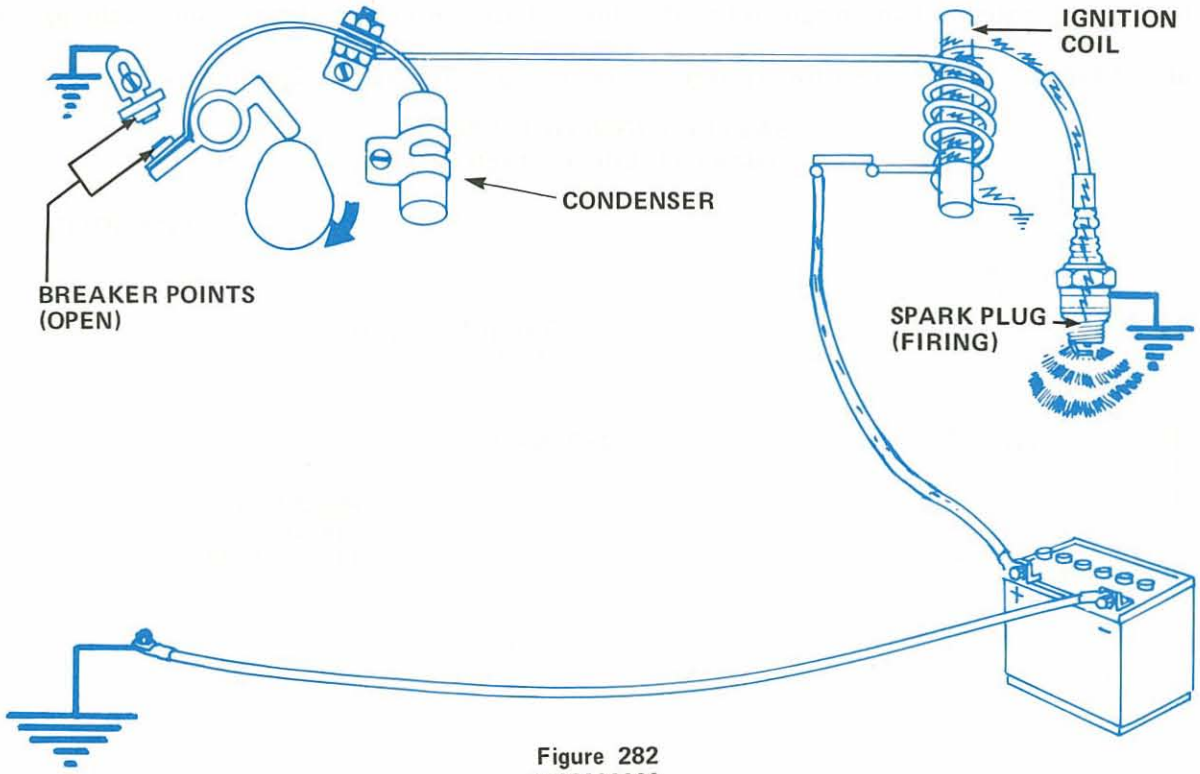
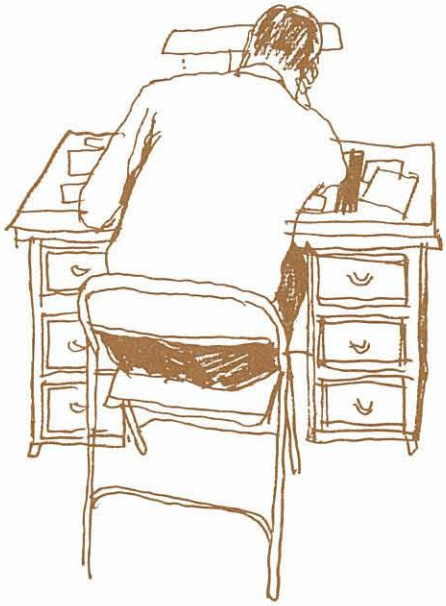


Figure 282

Figure 282 shows the points in the open position. The cam has moved so it opens the moveable part of the points. This immediately breaks the primary circuit. There is no current flowing in the primary circuit at this time. The sudden collapse of the primary circuit causes a high voltage surge that goes to the spark plug. This voltage is high enough to jump the gap at the plug and return to ground.

As soon as the circuit returns to ground the rotor turns so it is back in the position at Figure 281 with the points closed and no voltage in the secondary circuit. The only basic difference in the battery system and the magneto system is the switch is always closed in a battery system and always open in a magneto system while the engine is running. The condenser used in the battery system serves the same purpose as in the magneto system. It prevents arcing at the points and aids in producing a stronger spark.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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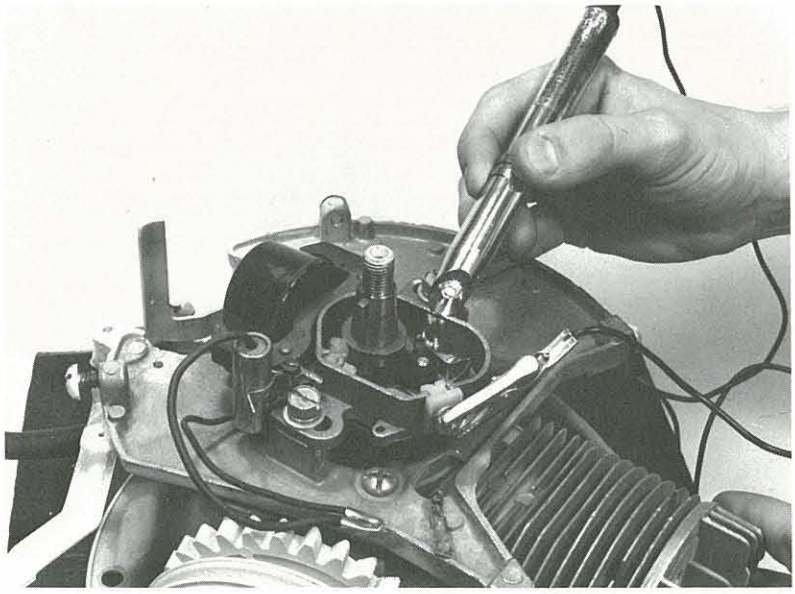
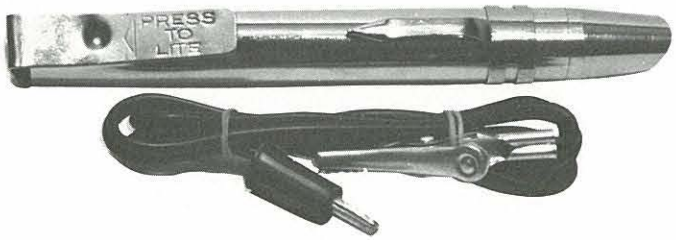
SMALL ENGINE CONTINUITY TESTER



Here's just what you need to determine contact point opening for setting the magneto timing on models with adjustable timing. This is a **must** for any Small Engine Repair Shop. Without this tester, many hours can be wasted in trying to set the timing by trial and error. The tool is amazingly easy to use.

First, set the piston at the proper position at BTDC, then simply attach the alligator clip to the moveable part of the breaker point assembly. Next, ground out the tip of the tester on any part of the engine. Rotate the stator plate back and forth until the points just start to open. The light will be on when the points are closed, but will go out just as soon as the points start to open. When the points start to open and the light goes out, tighten down the bolts to the stator plate assembly. The magneto is now timed to the engine.

This is truly a quality piece of test equipment, and is fully guaranteed. We have made a special purchase direct from the manufacturer and are able to pass the savings directly on to you. The unbelievable low cost is only $10.20. This tool will pay for itself on your very first job. Order now, as this is a special purchase and supplies are limited.



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EXAMINATION ON LESSON 28
MAGNETO TIMING

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INSTRUCTIONS:

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence form provided. Please do not put questions or other correspondence on this Examination.

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The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. An armature air gap of about _____ is generally acceptable for most small engines. ____
   a. .050"
   b. .0075"
   c. .085"

2. One basic difference in the battery system and the magneto system is the switch is always open in a battery system, and always closed in a magneto system when the engine is running. ____
   TRUE
   FALSE

3. Every upstroke on a two cycle engine is a compression stroke. ____
   TRUE
   FALSE

4. If the points are set too close, they will retard or slow the timing. ____
   TRUE
   FALSE

5. On most two cycle and four cycle engines, the ignition firing will be about 3/16 inch before the piston reaches top-dead-center. ____
   TRUE
   FALSE

6. The air gap is the space between the laminated iron cores and the magnets. ____
   TRUE
   FALSE

7. TDC is the abbreviation for top-dead-center. ____
   TRUE
   FALSE

8. At top-dead-center, on the compression stroke, the valves in a four cycle engine are both _____. ____
   a. open
   b. closed
   c. intake open, exhaust close

9. When the points are set too far apart, the spark will occur too soon. ____
   TRUE
   FALSE

(Continued on page 2)

10. BTDC is the abbreviation for before-top-dead-center. _____
    TRUE
    FALSE

11. Slow timing causes the spark to occur too _____. _____
    a. soon
    b. late
    c. makes no difference

12. Current supplied from a battery is high voltage. _____
    TRUE
    FALSE

13. The stator plate assembly includes the coil and the laminated yoke. _____
    TRUE
    FALSE

14. When the points are set too close, the spark will occur late. _____
    TRUE
    FALSE

15. On the compression stroke of a four cycle engine, both valves are _____. _____
    a. closed
    b. open
    c. intake open, exhaust closed

16. Every other upstroke on a four cycle engine is an exhaust stroke. _____
    TRUE
    FALSE

17. The frame on a engine acts as a ground for the entire electrical system. _____
    TRUE
    FALSE

COURSE Of

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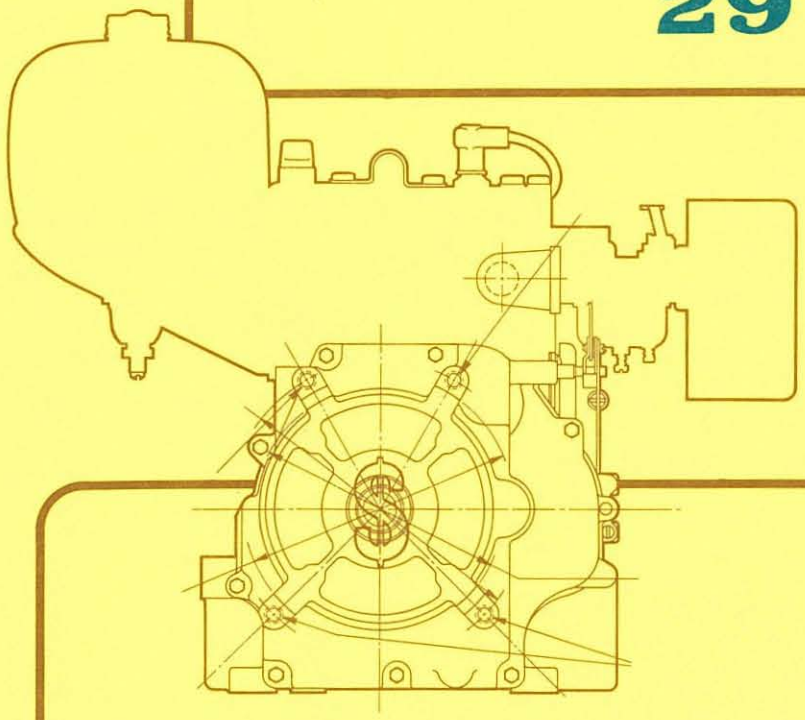
Repair & Service

LESSON NUMBER

29



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TWO AND FOUR CYCLE VALVE ACTION

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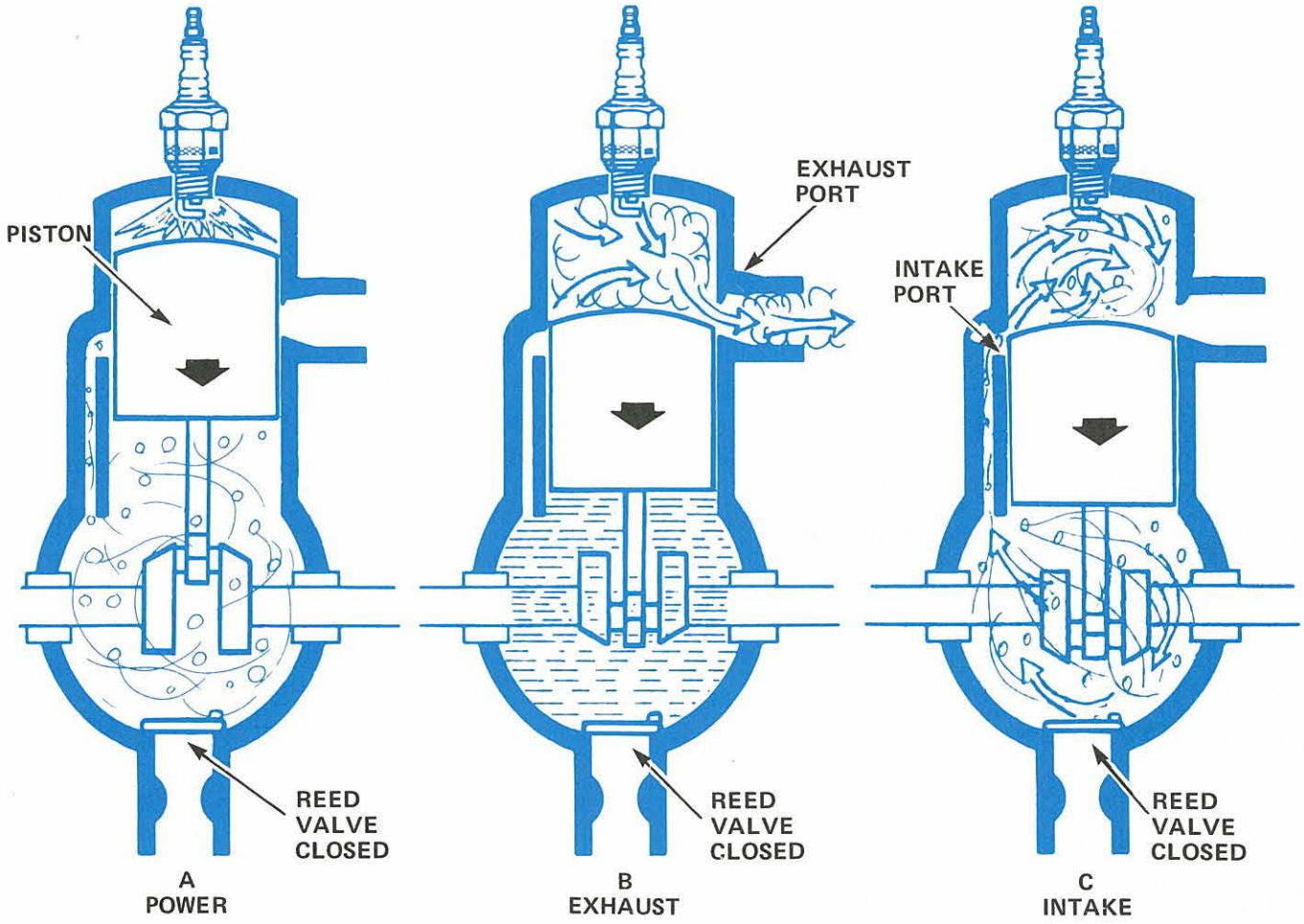


Figure 283

2-CYCLE STROKE

Before we go into the valve action of the 2-cycle engine, let's review some of the basic operating functions. A 2-cycle engine is designed to complete all of the actions necessary for a complete cycle during one revolution of the crankshaft. This is one stroke down and one stroke up.

Figure 283 shows the three actions that take place in the first stroke. The power stroke shown at A occurs just after the spark plug ignites the compressed fuel and air mixture. The exhaust stroke is shown at B. The piston is traveling down due to the explosion of the fuel and air mixture. As the piston moves down it uncovers the exhaust port allowing the burnt gases to escape. As the piston moves further down, as shown at C, it begins to uncover the intake port. This allows a new fuel and air mixture to enter the combustion chamber. This mixture is forced up and through the intake port by the pressure the piston exerts on it as the piston moves down in the cylinder. Notice the reed valve is closed in all three phases of stroke 1.

Figure 284 shows stroke 2. There is only one phase of this stroke. As the piston begins to go up, it opens the reed valve and draws in fuel, air and oil mixture from the carburetor. At the same time, it closes both the intake port, shown at A, and the exhaust port shown at B.

The action of the valves in any small engine is part of the timing of the engine. The valve action must do certain things at a certain time. The valve action of a 2-cycle engine is controlled by the action of the piston. The piston opens and closes the valves either by covering the valve ports or creating high and low pressure areas in the crankcase.

STROKE 2

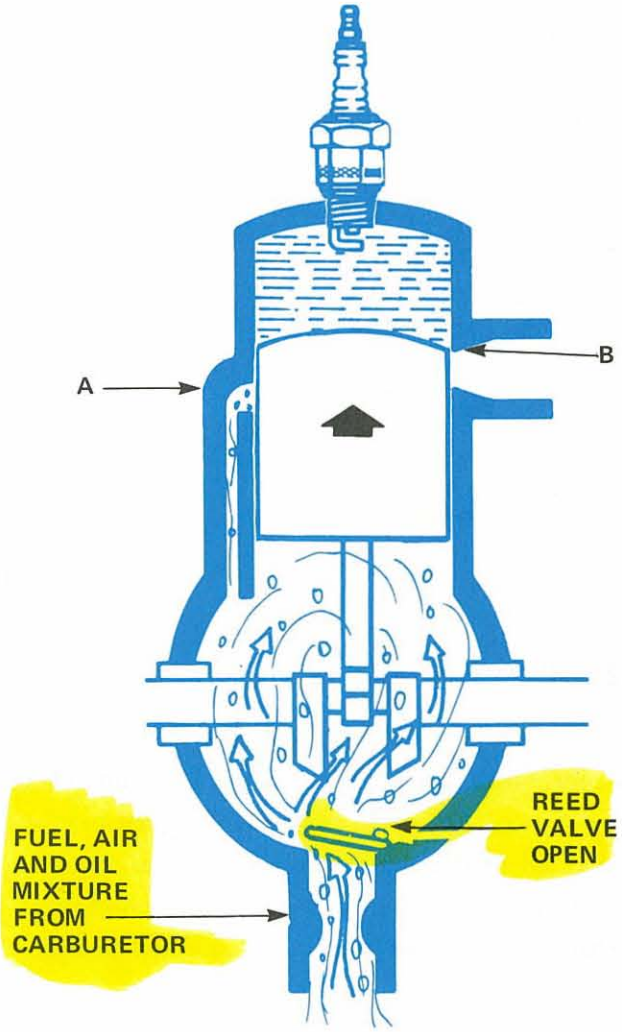


Figure 284

2-CYCLE VALVE ACTION

Sometimes 2-cycle engines are referred to as having only one valve. Actually they have only one moveable valve which is the intake. The exhaust valve is just an opening that is uncovered by the piston at the proper time.

The reed valves on 2-cycle engines are always located between the carburetor and the crankcase. These valves are made of a thin spring steel, plastic or other material that has the capability of flexing back and forth constantly.

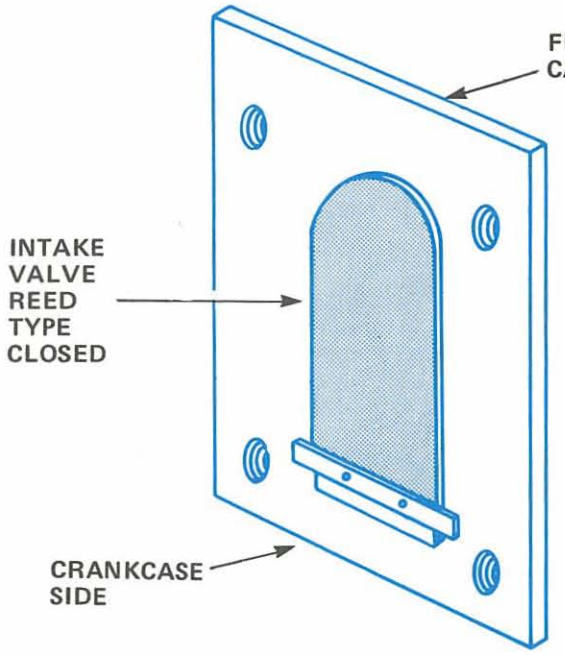


Figure 285

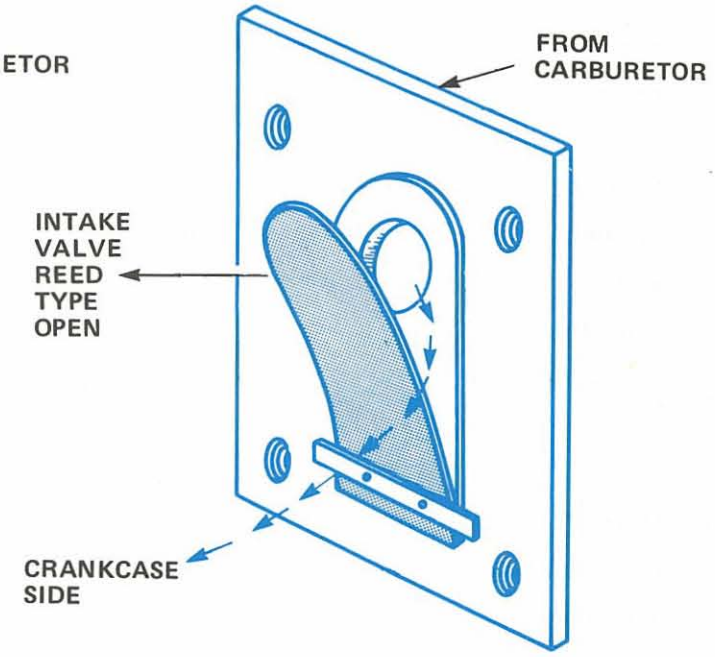


Figure 286

Figure 285 shows the reed valve in the closed position. This would be the condition of the valve on stroke 1, as shown in Figure 283. The piston would be on the down travel and exerting pressure on the lower part of the crankcase. This pressure keeps the valve closed when the piston is on the down stroke.

When the piston is traveling up on stroke 2, as shown in Figure 284, it creates a vacuum or low pressure area in the crankcase. When this happens, the reed valve opens as shown in Figure 286. This valve will either be in the open or closed position, as shown in Figures 285 and 286, at all times. Stroke 1 is always closed and stroke 2 is always open if the valve is operating properly.

Seldom do these reed valves cause trouble. If they do not function properly or, if they leak, they will allow the fuel, air and oil mixture to be forced back into the carburetor. When this happens it decreases the pressure in the crankcase. Figure 287 shows what happens when the reed valve is not functioning properly. If it is open on the down stroke of the piston, as shown at A, it will force part of the fuel mixture back to the carburetor at B instead of through the intake port C and into the combustion chamber.

Common failures of the reed valve are carbon build-up under the reeds; broken, bent or burnt reeds. Leaky reed valves will cause a loss of power because the pressure loss decreases the fuel charge entering the combustion chamber. This results in lack of complete combustion necessary for efficient operation of the engine.

If the engine is hard to start and tends to spit back through the carburetor when starting, it is quite possibly caused by the reed valve not functioning properly. Check for signs of blow back in the carburetor throat next to the reed valve.

There are several designs used by different manufacturers and they are sometimes called leaf valves and other similar names.

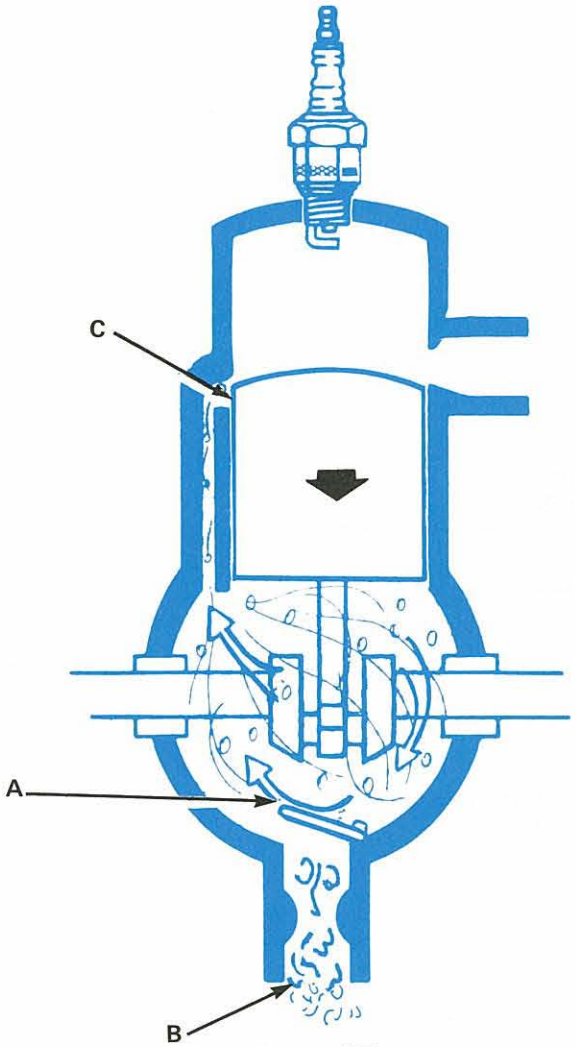


Figure 287

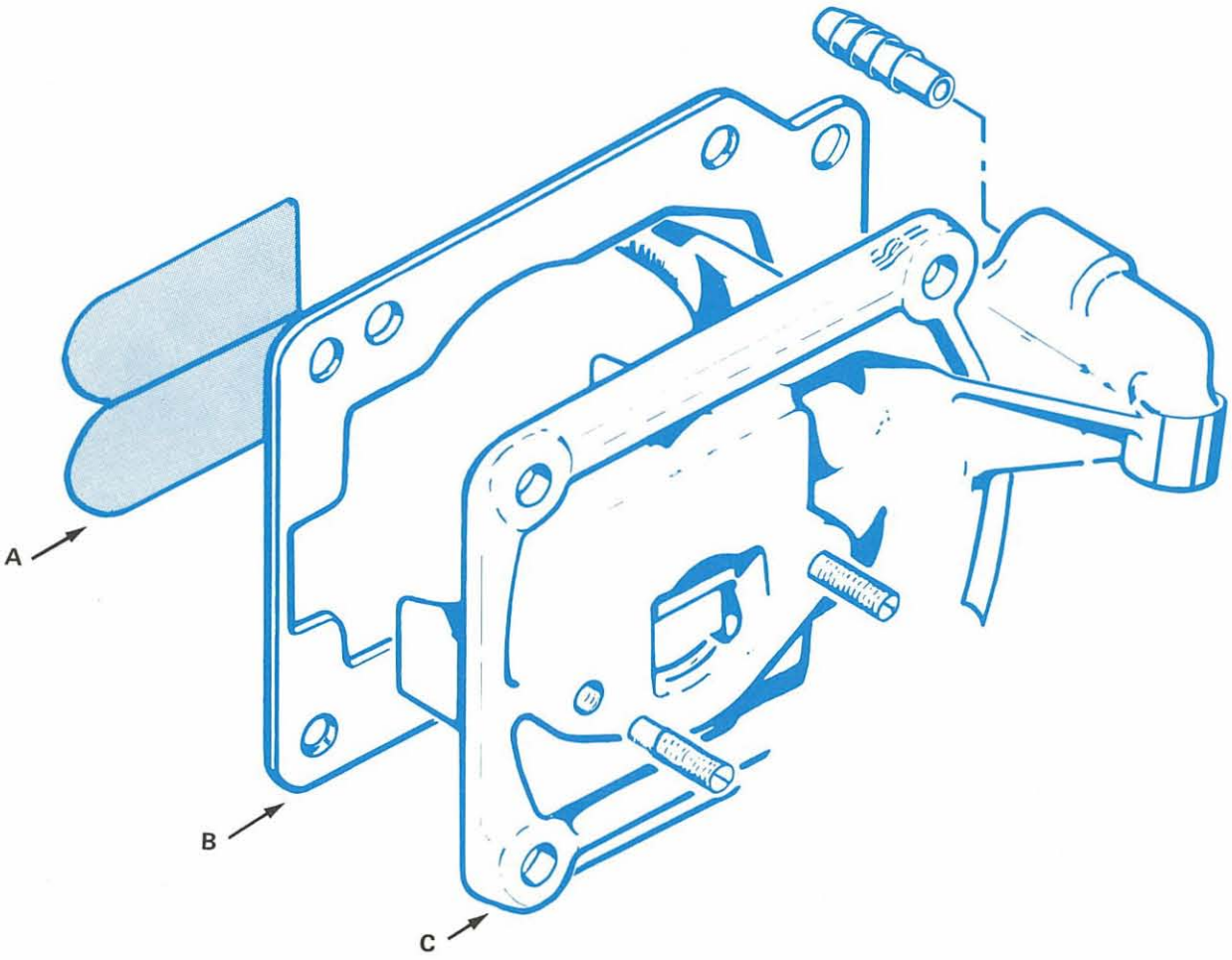


Figure 288

Figure 288 shows a typical reed valve assembly used on many small engines. The reed valve is shown at A. Sometimes they will consist of two reeds as shown and sometimes there will be four reeds. The manifold gasket is shown at B and the manifold at C.

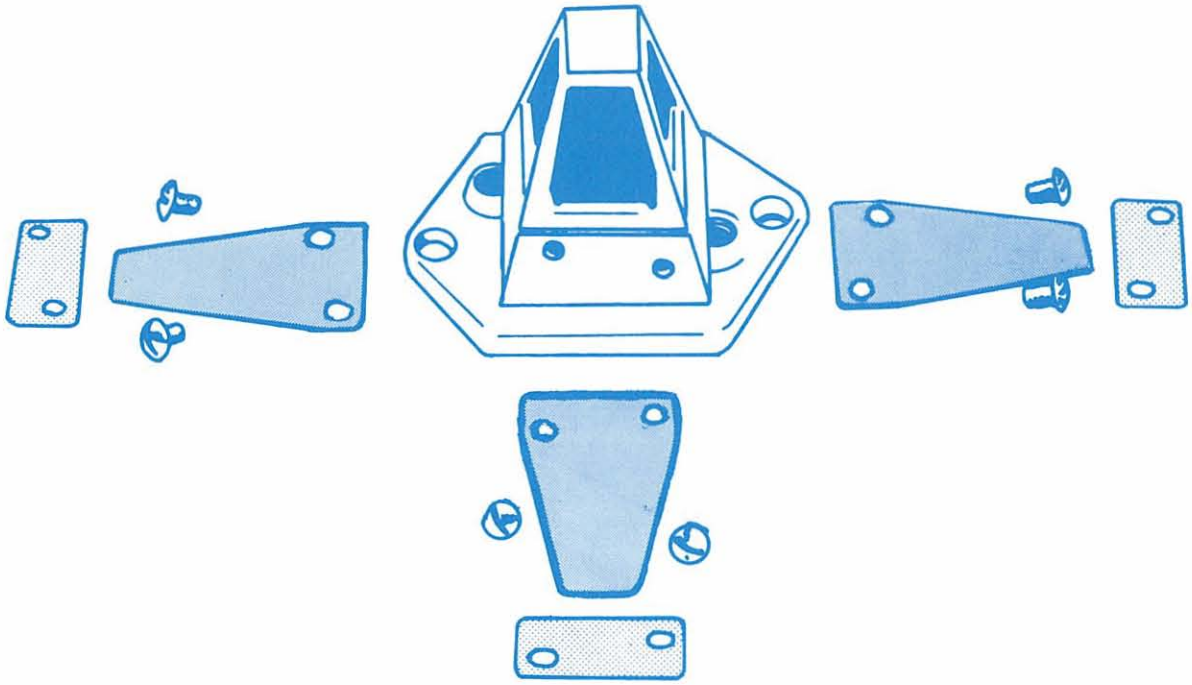


Figure 289

Another type of reed valve is shown in Figure 289. This valve uses four reeds, one on all four sides of the manifold section holding them. The different configurations used does not effect their function. These different designs all operate on the same basic principle. When in doubt as to the condition of the reed valves, it is always best to replace them with new ones as the cost is reasonable.

4-CYCLE STROKE

As we covered earlier, the 2-cycle engine completed all the actions necessary for a complete cycle during one revolution of the crankshaft. The 2-cycle engine fired every time the piston reached the top of the cylinder. The 4-cycle engine fires every second time the piston reaches the top of the cylinder or every two revolutions of the crankshaft.

4-CYCLE VALVE ACTION

On valves on 4-cycle engines, although they accomplish the same basic results as the reed valves and ports on the 2-cycle engine, the construction and operation is quite different. The valves on 4-cycle engines have three functions. They must provide an inlet for the fuel-air mixture to enter the combustion chamber. They must seal the combustion chamber for compression and ignition of the fuel-air mixture. Finally, they must allow the burned gases to escape so the cycle can be repeated.

Figure 290 shows the power and the exhaust stroke. In the power stroke the spark plug has just fired and the piston is moving down. Both the intake valve at A and the exhaust valve at B are closed. Since both of the valves are closed the explosive force is all directed against the top of the piston. This forces it down as far as it will go.

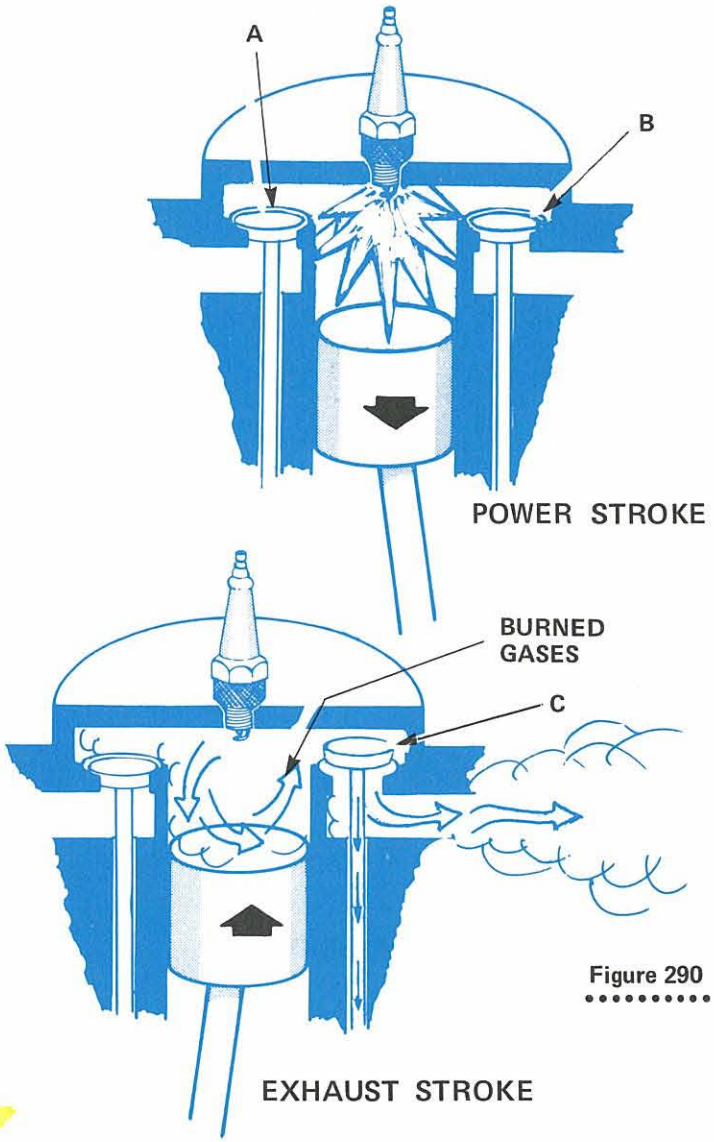


Figure 290

Notice when the piston begins to come back up on the exhaust stroke the exhaust valve shown at C opens allowing the burnt gases to escape out the exhaust valve opening. At this point the crankshaft has made one complete revolution when the piston reaches the top of the cylinder and the intake valve is closed. At this point the exhaust valve is open.

INTAKE

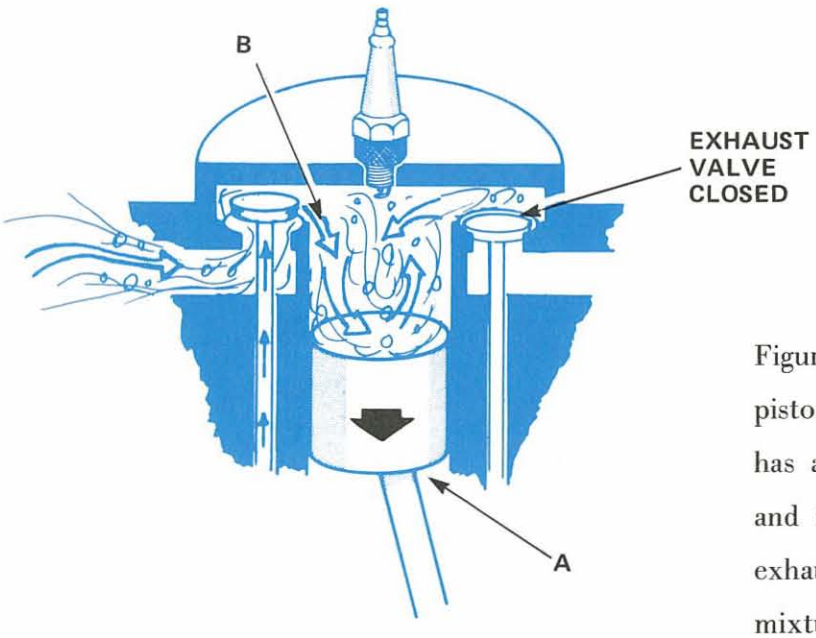


Figure 291 shows the next two strokes. The piston shown at A is on the intake stroke. It has already reached the top of the cylinder and is on the way down. At this time the exhaust valve closes and the fuel and air mixture enters at the intake valve at B.

The compression stroke is shown at C. The intake valve has allowed the fuel-air mixture to enter the combustion chamber. The intake valve then closes. The exhaust valve remains closed. As the piston reaches TDC, combustion occurs again and the piston is again on the power stroke. The intake stroke and the compression stroke take one complete revolution of the crankshaft, making a total of two revolutions to complete the cycle of this 4-cycle engine.

COMPRESSION

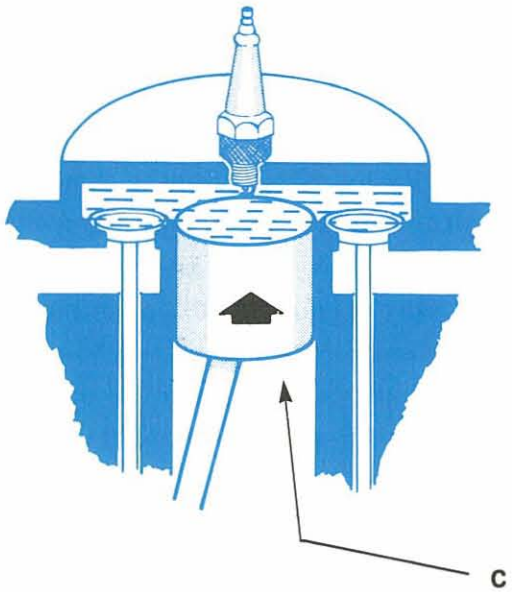
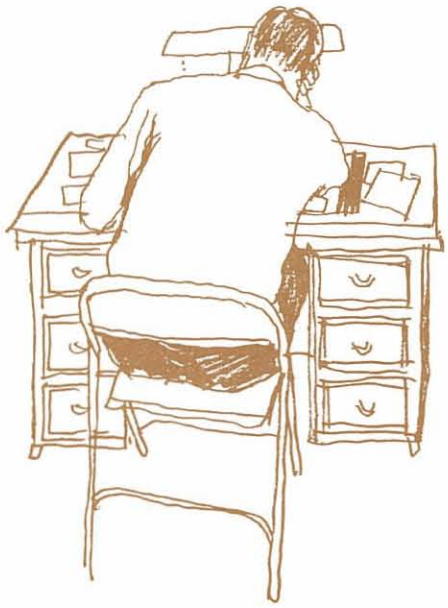


Figure 291



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- If more than one lesson has been completed, return no more than two examinations per envelope.
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EXAMINATION ON LESSON 29
TWO AND FOUR CYCLE VALVE ACTION

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The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. The reed valves on a two cycle engine are always located between the carburetor and the crankcase. _____
   TRUE
   FALSE

2. As the piston moves up on a two cycle engine, it closes the intake port and also the exhaust port. _____
   TRUE
   FALSE

3. Four cycle engines fire every _____ revolutions of the crankshaft. _____
   a. one
   b. two
   c. three

4. On a compression stroke on a four cycle engine both valves are open. _____
   TRUE
   FALSE

5. A _____ cycle engine completes all of the actions necessary for a complete cycle during one revolution of the crankshaft. _____
   a. one
   b. two
   c. four

6. As the piston on a two cycle engine begins to travel upwards, it opens the reed valve. _____
   TRUE
   FALSE

7. When the piston on a four cycle engine is on the intake stroke, it is on the way up. _____
   TRUE
   FALSE

8. If the reed valves do not function properly, they can allow fuel to be forced back into the carburetor. _____
   TRUE
   FALSE

(Continued on page 2)

9. The power stroke on a two cycle engine occurs just _____ the spark plug ignites the fuel mixture. _____
   a. before
   b. after
   c. neither of the above

10. When the piston on a two cycle engine is traveling up, it creates a low pressure area in the _____. _____
    a. combustion chamber
    b. exhaust area
    c. crankcase

11. The action of the valves of any small engine is part of the timing of the engine. _____
    TRUE
    FALSE

12. On the exhaust stroke on a two cycle engine, the piston is traveling upwards. _____
    TRUE
    FALSE

13. If a two cycle engine is hard to start and spits back through the carburetor, it is very possibly caused by the carburetor being dirty. _____
    TRUE
    FALSE

14. The valve action on a two cycle engine is controlled by the action of the piston. _____
    TRUE
    FALSE

15. The reed valves on a two cycle engine is closed on the power, exhaust, and intake strokes. _____
    TRUE
    FALSE

16. On the power stroke on a four cycle engine, both the intake and exhaust valves are _____. _____
    a. open
    b. closed
    c. neither of the above

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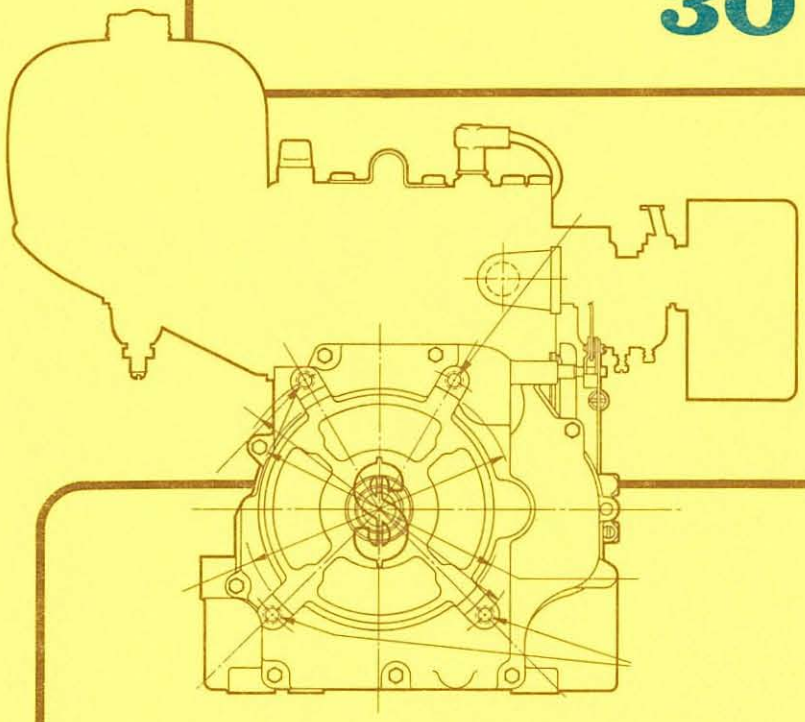

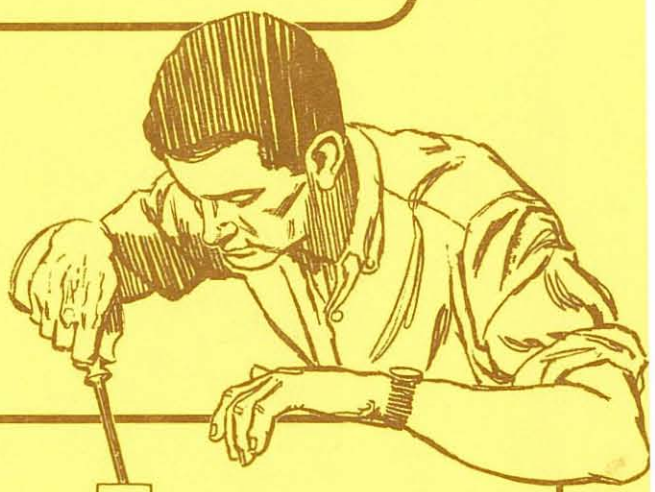

TURN THIS PAGE

...and let's find out all about --

FOUR CYCLE VALVE ASSEMBLY

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4-CYCLE VALVE IDENTIFICATION

There are two valves in single cylinder 4-cycle engines. Their construction is very similar except they are made of different material. The exhaust valve is made of a very hard material that will withstand the extreme heat that it operates under.

Some engines have the exhaust valve on the left as you face the exhaust and the intake valve on the right. Others have them reversed. When installing new valves you can always tell the valves apart by their appearance. The exhaust valve is a light shiny metal when new and the intake valve has a blueish appearance. Often the intake valve is marked with an "I" on the top.

After valves have been operated in an engine there is no problem telling them apart. The intake valve retains the clean blue appearance while the exhaust valve will be coated with light gray carbon deposits.

Figure 292 shows an intake and exhaust valve. The intake valve is shown at A and the exhaust valve at B. The exhaust valve coating will become heavier with engine use.

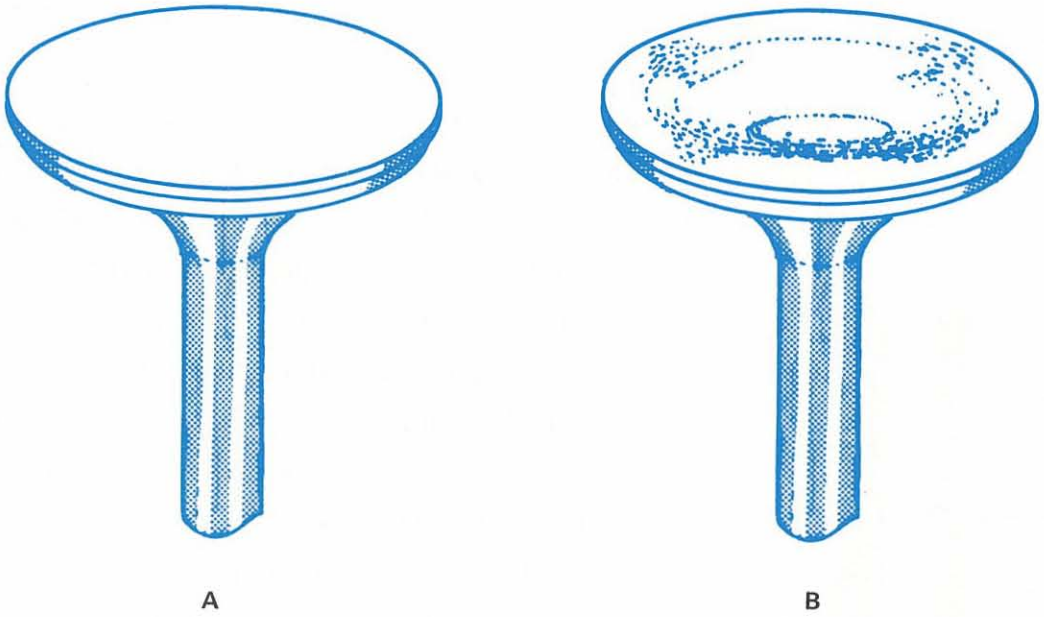


Figure 292

PARTS OF THE VALVE

Figure 293 shows the parts of the valve. Study the names of these parts as we will be referring to them later. The parts we will be most concerned with in general valve maintenance, are the margin shown at A, the face shown at B and the seat shown at C. These are the three areas of the valve requiring the most maintenance. There are other wear parts such as the stem D and the guide E but the margin, seat and face are the three key areas of valve maintenance.

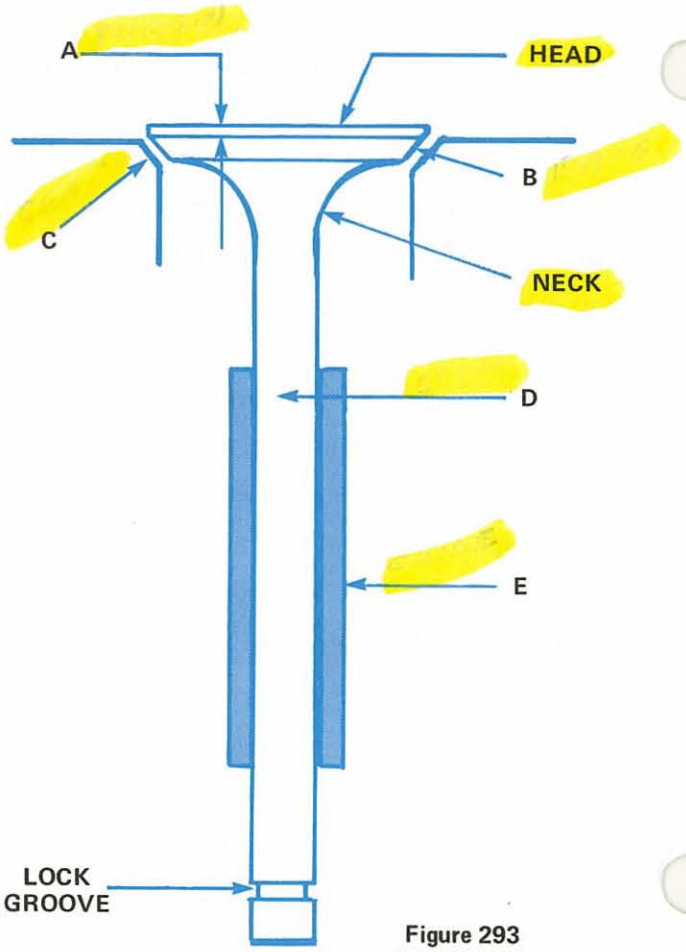


Figure 293

PARTS OF THE VALVE ASSEMBLY

The valve assembly consists of the valves, springs and retainers. Figure 294 shows a typical valve assembly for a single cylinder, 4-cycle engine. The exhaust and intake valves are shown at A. These are not interchangeable. The upper valve spring cap, shown at B, is interchangeable. The valve springs, shown at C, should not be interchanged even though they may appear to be identical in appearance. On some engines the exhaust valve spring may appear identical but is actually heavier than the intake spring. As a precaution, it is a good idea to always replace the spring in the side it was removed from. The lower valve spring cap is shown at D. These are interchangeable but not with the upper valve spring caps shown at B. The valve lifters are shown at E. These are generally interchangeable but it should be avoided if possible. The valve lifters work directly off the lobes of the camshaft.

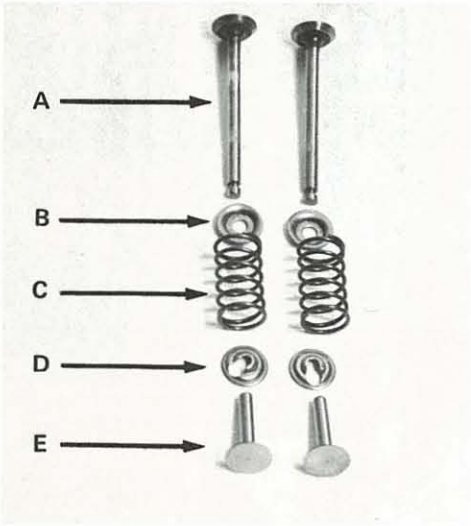


Figure 294

Figure 295 shows the valve assembly and its relationship with the camshaft. There are two lobes, or cams, shown at A. As the cam shaft rotates, these cams raise and lower the valve lifters shown at B. These, in turn, raise and lower the valves at C. The space between the valves and the lifters is known at the valve-tappet clearance. This distance will generally not be the same for both the exhaust and intake valves.

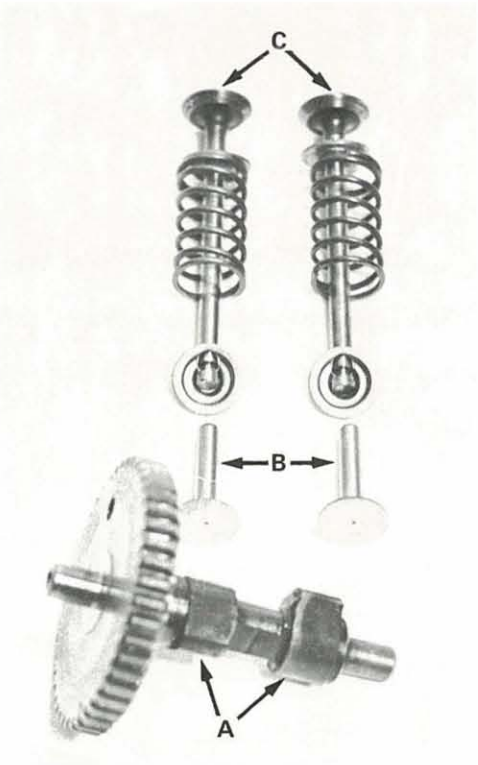


Figure 295

The lower valve spring cap, shown in Figure 294, is one of several designs used. Figure 296 shows several other designs you can expect to find in different small engines.

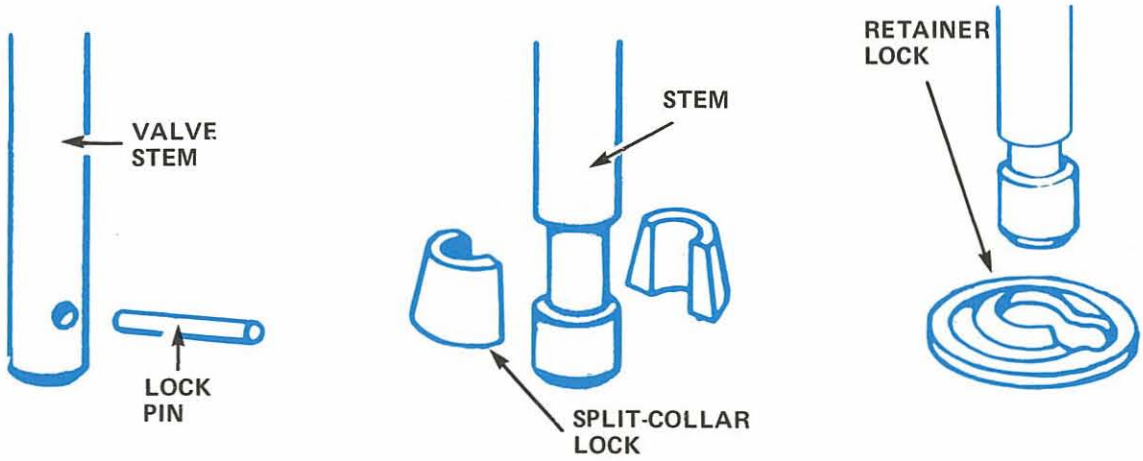


Figure 296

4-CYCLE VALVE DAMAGE

Valve damage can be caused by extended use of the engine without having the valves checked and serviced regularly. There are two conditions that will generally show up when a valve is damaged. The burnt valve, shown in Figure 297, is the most common valve damage. The margin and face of the valve shown at A are burned and part of the metal has started to deteriorate. This condition is caused by gases escaping by the valve. This happens when the valve clearance is too small or if the valve does not seat properly. Valve clearance is the space between the valve stem and the valve lifter. We'll go more into valve clearances just a little later.

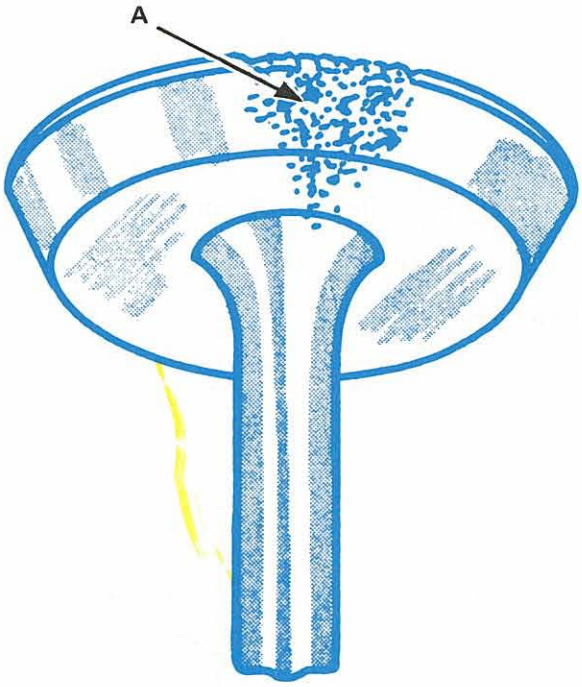


Figure 297

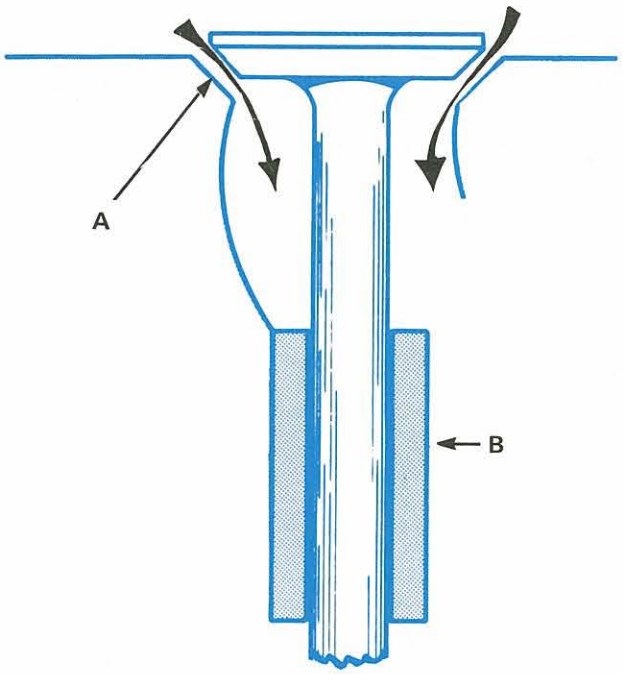
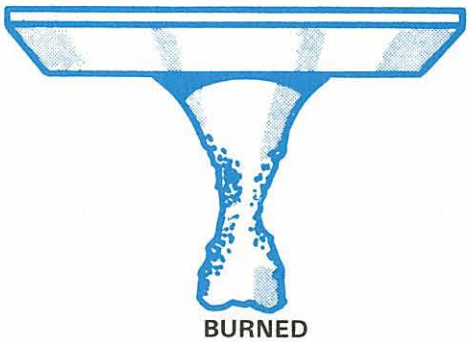


Figure 298

If the valve does not seat properly it will not completely close as shown in Figure 298. This allows burning gases to escape around the valve seat shown at A. These hot gases will deteriorate both the valve and the valve seat very rapidly. This condition is known as blow-by and is also caused by failure of a valve to close completely because of the stem binding in the valve stem guide shown at B.

This sticking occurs more on exhaust valves and is caused by lead, carbon, gum and varnishes from the fuel. This build-up of material between the guides and the valve stem can cause enough friction and drag to keep the valve from opening or closing completely. Continued operation under these conditions will cause the valve to burn.

Another valve damage condition is shown in Figure 299. This is a burned stem. The temperature around the stem of the valve can run over 1000 degrees F. When metal reaches extreme temperatures, it tends to begin deteriorating and becomes soft. If metal is heated to just below its melting point it can very easily be bent or stretched. This is what will cause the condition of the valve shown in Figure 299. The stem has become hot enough, almost to the melting point. The impact of the valve hitting the valve seat when it closes will elongate the stem or stretch it.



BURNED STEM

Figure 299

4-CYCLE VALVE OPERATION

Earlier we covered the construction of the valve assembly and its parts. Figure 300 shows the parts that make the valves work and their relationship to the engine. Study these parts carefully so you will be familiar with the names as we will be referring to them frequently.

The spring, shown at A, keeps the valve closed unless pressure is exerted on the valve B to lift it up. There is a retainer on each end of the spring to keep the spring in place.

The crankshaft gear, shown at C, is attached directly to the crankshaft and turns at the same speed as the crankshaft. This gear is shown rotating clockwise. The crankshaft gear engages the camshaft gear at D and turns it in the opposite, or counterclockwise direction. The camshaft gear at D is twice as large as the crankshaft gear at C.

Some small engines have 22 teeth on the crankshaft gear and 44 teeth on the camshaft gear. Some have 19 teeth on the crankshaft gear and 38 teeth on the camshaft gear. This means that the crankshaft gear must make two revolutions to drive the camshaft gear one revolution.

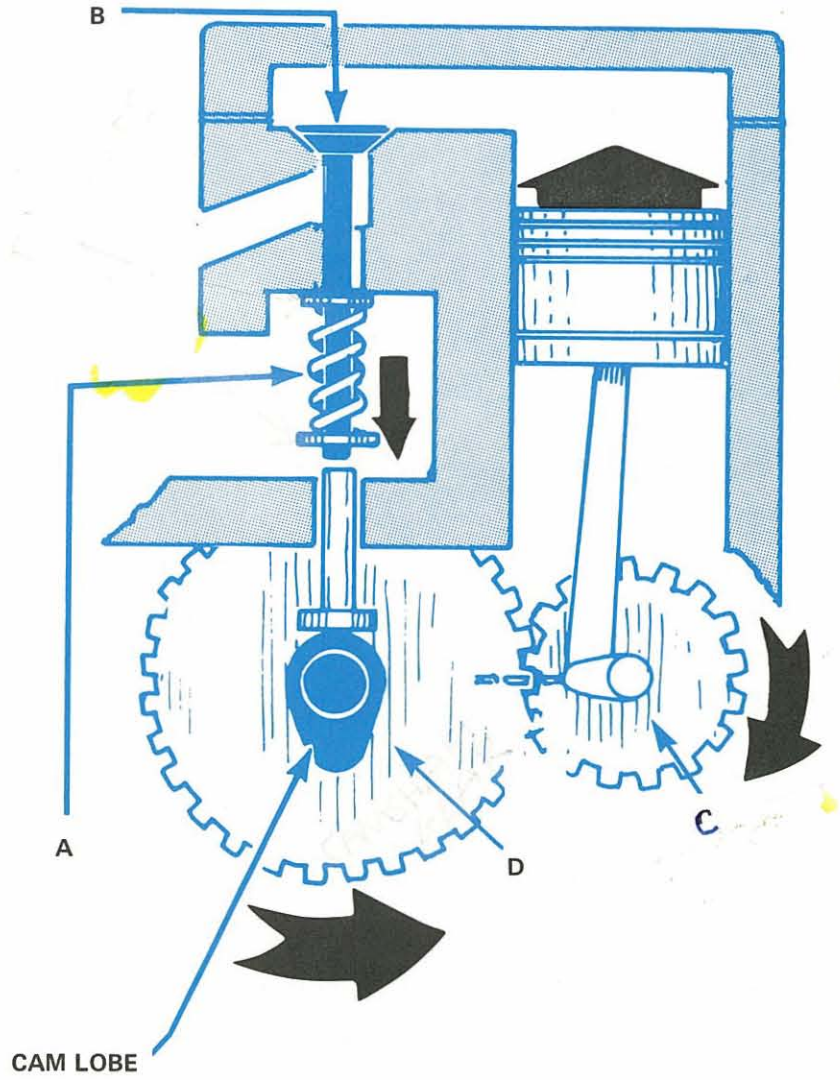
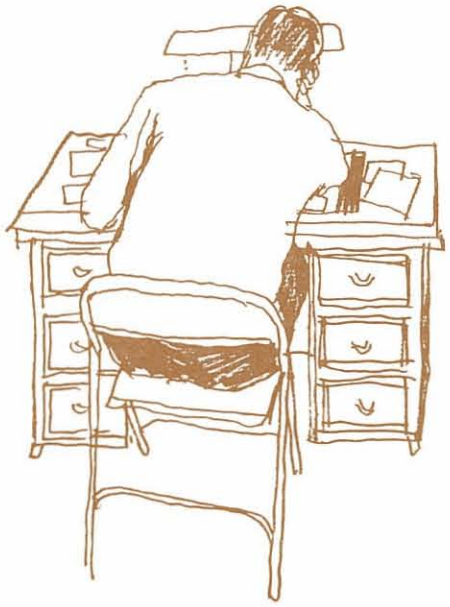


Figure 300



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FOUR CYCLE VALVE ASSEMBLY

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence Forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Valve springs are always interchangeable as long as they appear identical in appearance. _____
   TRUE
   FALSE

2. The space between the valves and the lifters is known as the _____ clearance. _____
   a. valve tappet
   b. skirt clearance
   c. margin setting

3. The areas of valves requiring the most maintenance are _____. _____
   a. margin
   b. seat
   c. face
   d. all of the above

4. Burnt valves are caused by gasses escaping by the valves. _____
   TRUE
   FALSE

5. The _____ valve is made of a material that will withstand extreme heat. _____
   a. intake
   b. exhaust
   c. both of the above

6. Valve sticking occurs more on intake valves. _____
   TRUE
   FALSE

7. Valve lifters work directly off the lobes of the _____ on most small engines. _____
   a. camshaft
   b. crankshaft
   c. rod

8. After valves have been operated in an engine, the _____ valve retains the clear blue appearance. _____
   a. exhaust
   b. intake
   c. both of the above

(Continued on page 2)

9. If a valve does not seat properly, it will allow gasses to escape around the _____. _____
   a. cam
   b. valve lifter
   c. valve seat

10. As the camshaft rotates, the valve lifters raise and lower the valves. _____
    TRUE
    FALSE

11. The valve assembly consists of _____. _____
    a. rings, land, skirt
    b. valves, springs, retainers
    c. margin, head, stem

12. Valve tappet clearance would generally be the same for both the intake and exhaust valves. _____
    TRUE
    FALSE

13. Label the parts of the valve train shown in Fig. 30-1.
    crankshaft gear _____
    cam _____
    valve _____
    camshaft gear _____
    valve spring _____
    valve lifter or tappet _____

14. Label the parts of the valve shown in Fig. 30-2.
    face _____
    neck _____
    head _____
    stem _____
    margin _____
    guide _____
    seat _____
    lock groove _____

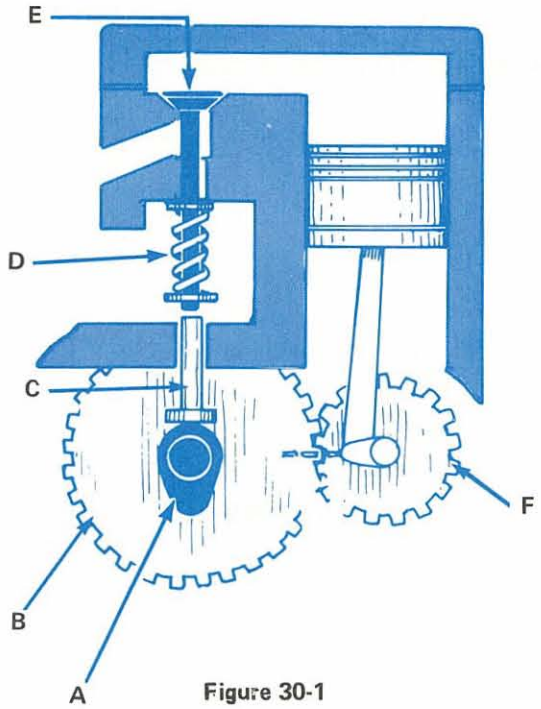

Figure 30-1

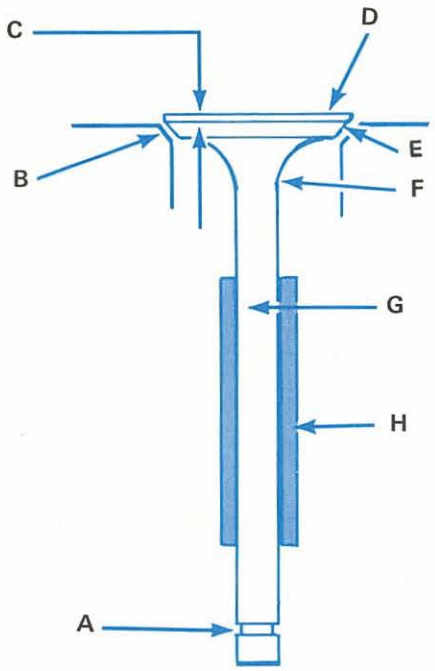

Figure 30-2

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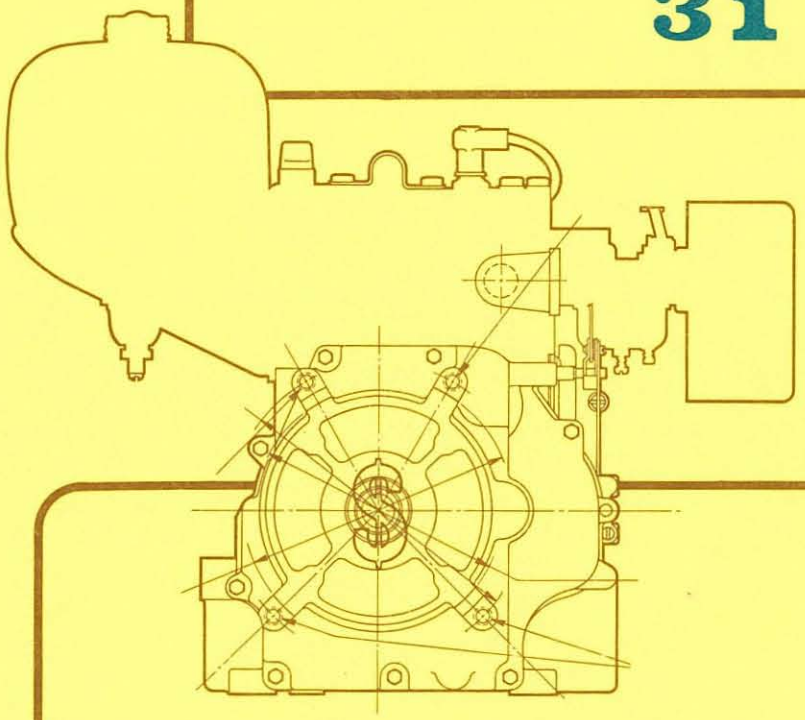
31



TURN THIS PAGE

...and let's find out all about --

FOUR CYCLE TIMING AND COMPRESSION TEST

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4-CYCLE VALVE TIMING

Unlike 2-cycle valves, 4-cycle valves must be set to be in time with the engine operation. Since the 4-cycle engine has only one power and one compression stroke during two revolutions of the crankshaft, we can set the crankshaft and the camshaft gears so they will have the cam in the proper position for opening or closing.

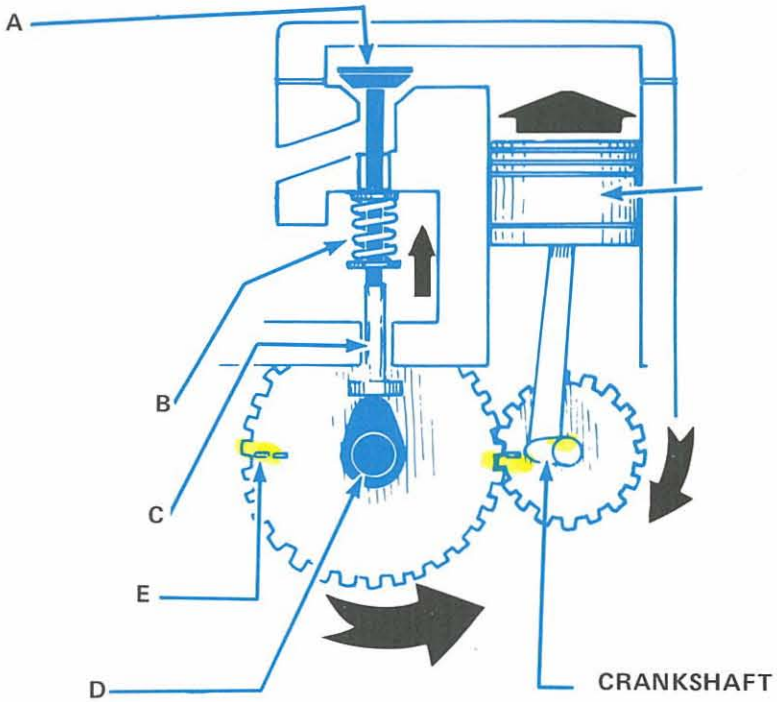


Figure 301

Figure 301 shows Valve A in the open position. The spring B is being compressed because the valve tappet C is riding on the high point of the cam on the camshaft at D. There is generally a mark on both the camshaft and the crankshaft gear. These are known as timing marks. Notice the position of the timing marks, shown at E, with the valve in the open position. The high point on the cam is lifting the valve against the spring tension.

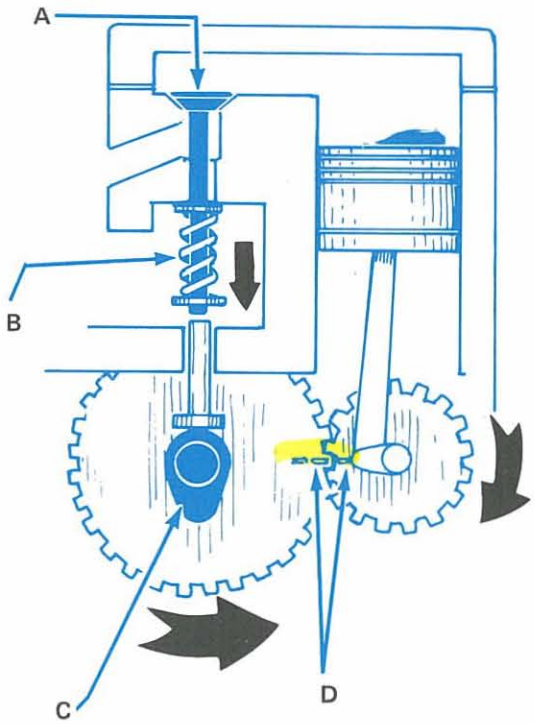


Figure 302

Now, when the crankshaft gear makes one revolution, as shown in Figure 302, the valve A is closed, the spring B is expanded and the valve tappet is riding on the low spot of the cam shown at C.

Notice the timing marks, shown at D, are now lined up. The crankshaft gear has made one revolution and the camshaft gear has made one-half revolution.

Any time these two marks are lined up together, as shown at D, the valves are timed to the engine. Seldom do they get out of time unless reassembled wrong or some of the gear teeth break off.

VALVE AND CAM FUNCTIONS

Earlier we covered the basic valve action as they relate to the four strokes of the engine. Both the intake and the exhaust valves are controlled indirectly by the location of the piston. The piston location is directly related to the valve function at any given location. This relationship of the piston to the valves is controlled by the timing gears.

Figure 303 shows a cross section of a typical single cylinder 4-cycle engine valve train. The piston is positioned on the intake stroke. It is traveling down and creating a vacuum above it. The intake valve A is open. This allows the fuel and air mixture to enter the combustion chamber. The crankshaft gear B is timed to the camshaft gear C so that the cam D raises the intake valve. This allows fuel to enter. The exhaust valve E is closed because the valve lifter F is riding on the low point of the cam and the valve spring keeps the valve closed.

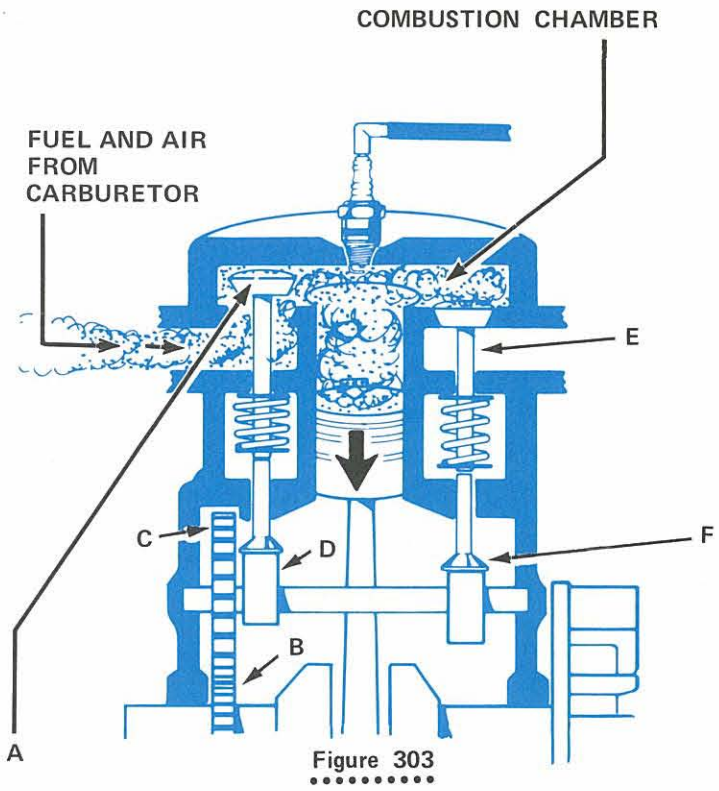
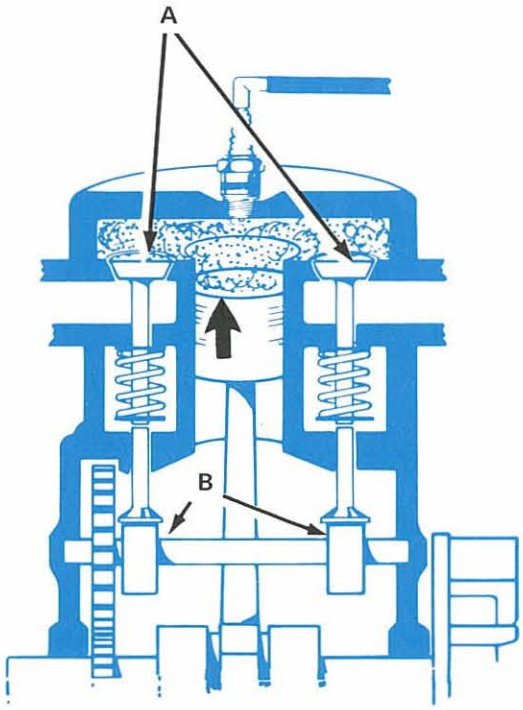


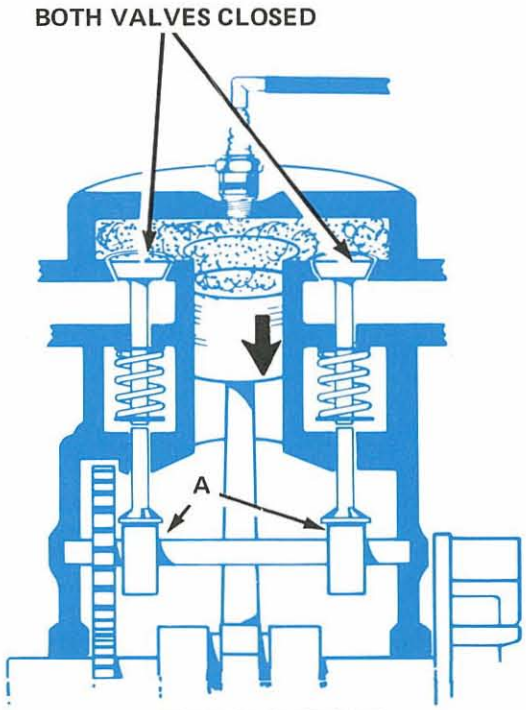
Figure 303

The next stroke is the compression stroke shown in Figure 304. The piston is traveling up. Both the intake and the exhaust valves, shown at A, are closed and the fuel-air mixture is trapped in the combustion chamber. Both valves are riding on the low part of the cams as shown at B. Spring tension closes both valves. At the proper time BTDC the spark plug ignites the fuel-air mixture, causing the explosion which forces the piston back down.



COMPRESSION STROKE

Figure 304

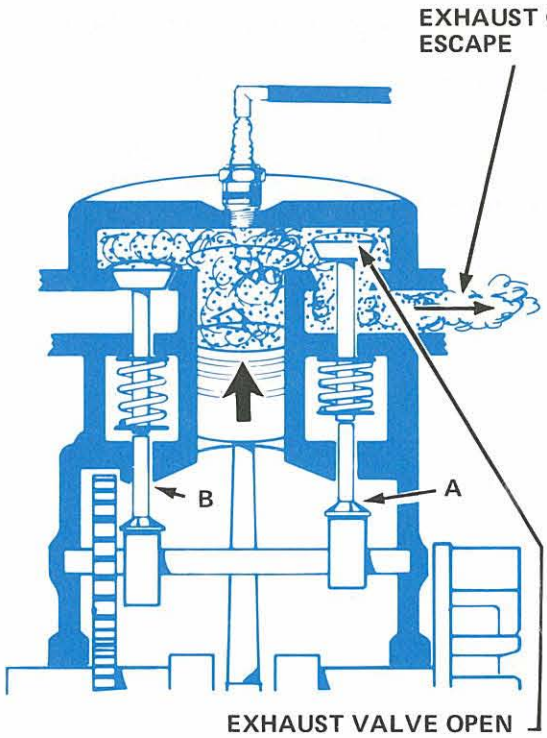


POWER STROKE

Figure 305

The power stroke is shown in Figure 305, just after the spark plug ignites the fuel-air mixture. Both valves are still closed. The only thing that can give is the piston because it is free to move down. The valve lifters are still riding on the low point of the cam, shown at A, and the spring tension keeps both valves closed.

Figure 306 shows the exhaust stroke. The valve lifter A is riding on the high point of the cam and opens the exhaust valve, allowing the burnt gases to escape. The valve lifter B is riding on the low point of the cam and the spring tension keeps the intake valve closed while the exhaust gases escape. The piston moving up forces the exhaust gases out through the exhaust. As soon as the piston forces the exhaust gases out it starts back down and begins the intake stroke again.



EXHAUST STROKE

Figure 306

If the marks on the timing gears are properly aligned, the gears are not damaged and there are no other defects such as a bad cam or valve lifter, the valves will be in the proper position for the intake, compression, power and exhaust stroke.

When studying the action of 4-cycle valves with an engine on your work bench, you may notice there is one point when both valves are slightly open. At the beginning of the intake stroke both valves are open slightly. It is hardly noticeable since they are both open only about .002-inch at the same time. This is called the "valve overlap".

VALVE COMPRESSION TEST

Hard starting, rough engine operation, loss of power and engine backfiring through the carburetor are some signs of valve trouble. Compression loss through other parts of the engine, such as rings and gaskets, can also cause these same problems. A compression test will not tell you exactly where the trouble is located. It will only tell you compression is being lost.

A compression test will help in analyzing an engine problem in that it will point definitely to the compression functions of the engine. This minimizes the trouble areas of ignition and carburetion. On the other hand, a good compression test would point the trouble to ignition and/or carburetion.

Good compression is very important and necessary for a smooth functioning engine. If valve trouble is suspected, check the compression. There are several other conditions that can effect compression other than bad valves and rings.

A dry cylinder that has not been used for sometime when an engine has been stored will not have oil in the piston and cylinder wall area. The presence of oil in this area helps make the seal necessary for good compression. If the oil drains away from the rings it will allow air to bypass and show as poor compression. Worn or broken piston rings, or a worn cylinder block along with a loose or broken spark plug are other factors that can effect compression.

A damaged or warped cylinder head or leaky head gasket are causes of poor compression along with sticking or burned valves. Under normal conditions poor compression will generally be traced to valves, bad rings or damaged head gasket.

The method of checking compression on small engines is controversial among small engine mechanics and engine manufacturers. Some think it necessary to use a compression gauge or an air pressure check while others believe that more simple tests are adequate.

Generally you can depend on the more simple method of feeling the compression as you turn the flywheel by hand. First remove the spark plug and turn the flywheel until the piston comes up on the compression stroke. On 4-cycle engines this will be every second revolution of the crankshaft. With your thumb covering the spark plug hole, as shown in Figure 307, you will feel a resistance of air being forced out of the cylinder when the piston is on the compression stroke. You can use either a pair of vice grip pliers to turn the crankshaft or pull the starter rope.

You will generally get a better feel of the compression by pulling the starter rope, or giving the flywheel a quick spin. A very noticeable force of air trying to escape from the cylinder is an indication of good compression.

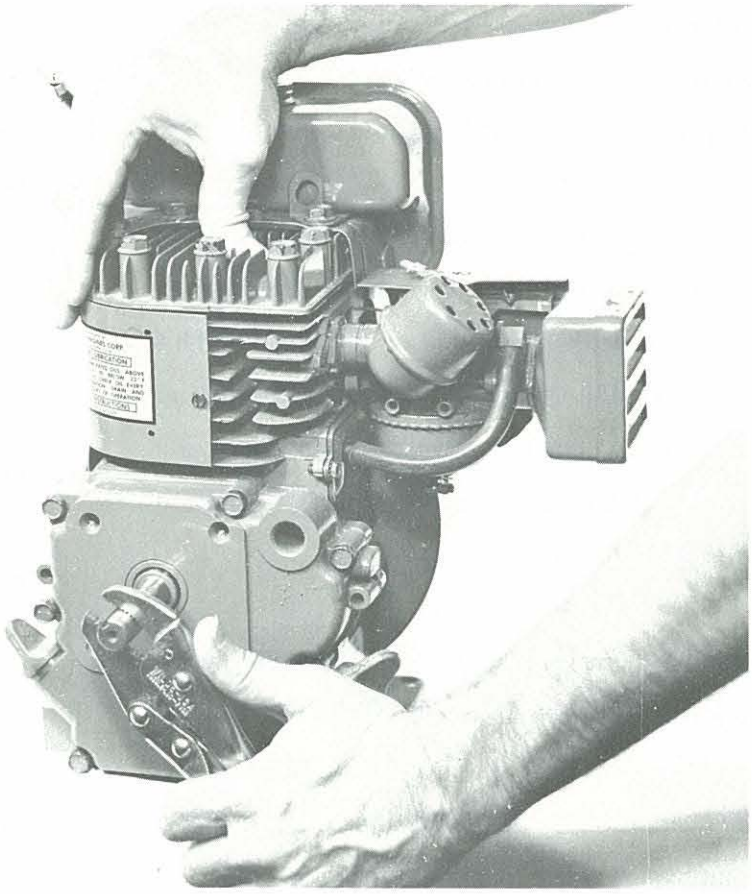


Figure 307

Some small 4-cycle engines now have a compression release mechanism that reduces the compression in the cylinder when the crankshaft is turned slowly. This makes easier starting and it releases to full compression as soon as the engine starts. Turning the crank in the opposite direction of normal rotation makes the compression release mechanism ineffective.

If bad compression is present, the crankshaft can be turned easily with little resistance. Very little compression will try to escape through the spark plug hole.

When working with 2-cycle engines you will notice a definite resistance on every revolution of the crankshaft instead of every second revolution as with 4-cycle engines.

Another method of checking compression is to force compressed air into the cylinder. A special tool, as shown in Figure 308, is available at most automotive supply houses and can be used to force air into the cylinder.

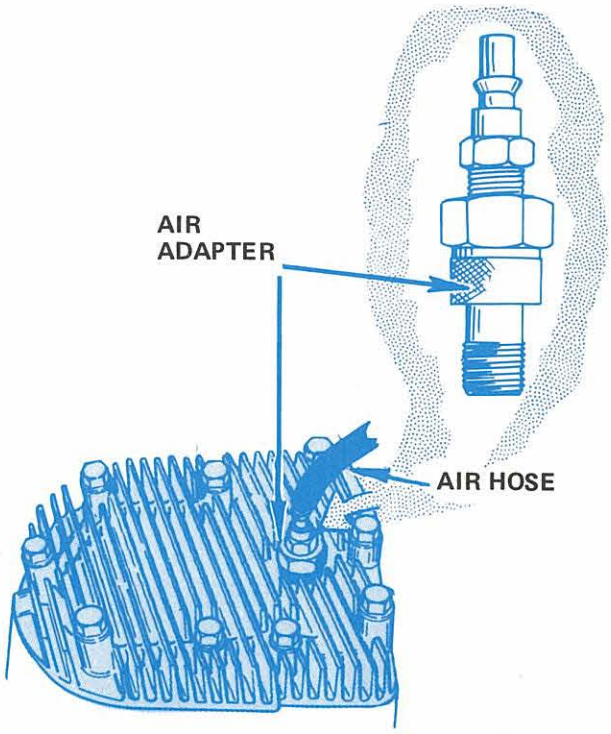


Figure 308

Insert the tool in the spark plug hole and rotate the crankshaft to TDC on the compression stroke. Remove the oil filler plug on 4-cycle engines and cover with a clean rag. If there is a leak around the piston rings it will blow oil out the filler hole. Use about 50 pounds of air pressure and connect the hose to the tool after it has been threaded into the spark plug hole. If you hear leaks through the muffler it would indicate a leaky exhaust valve. If air is heard through the carburetor, it would indicate that the intake valve is leaking. If the leak is heard through the oil filler hole, the trouble would very likely be either bad rings or a damaged cylinder.

COMPRESSION GAUGE

Most manufacturers and some repair shops do not believe a compression gauge test is necessary for small single cylinder engines. They feel the air pressure method or feel method is adequate. One of the reasons the gauge test is not necessary is the low cranking speed of most of these engines and the small displacement of the cylinder. On larger, or multi-cylinder engines the compression gauge can give much better information.

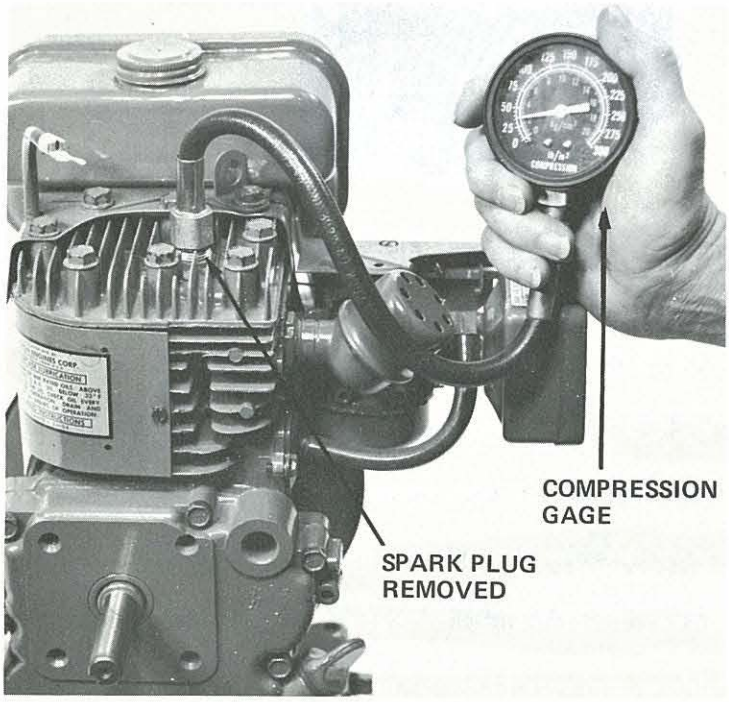


Figure 309

A typical compression gauge is shown in Figure 309. After the spark plug has been removed, insert the gauge in the hole by screwing it in finger tight and then adding about one-fourth turn with a plug wrench. Some gauges have a tapered rubber cone that can be held in place. Turn the engine 10 or 12 times at cranking speed or use the electric starter. The throttle should be fully open so as much air as possible can reach the cylinder. An engine in good condition should give a reading of 55 to 65 pounds pressure. If under 40 pounds, you can suspect trouble such as worn rings, bad head gasket or defective valves in 4-cycle engines.

After rotating the crankshaft enough to bring the reading up to maximum, carefully watch the gauge indicator. The needle should start dropping back very slowly. If the engine is in good condition, you should just be able to see the needle move. If any leakage is present the needle will move more rapidly.

The use of the compression gauge is much more important when working with multi-cylinder engines because it allows the service man to determine which cylinder is bad. When two or more cylinders are used in an engine, one or more of them can be bad and reduce the efficiency of the engine. The more cylinders added to an engine the less likely you would be able to notice trouble if only one cylinder was not functioning properly. Any one of the cylinders and its related functions, such as valves, rings and piston can cause that single cylinder to be operating at less than its rated capacity.

An actual visual inspection of the engine is the only sure way to locate and correct poor compression. You can easily feel any side play present in the piston, if the rings are worn and the condition of the valves will show signs of burning or leaking and whether or not they are seating properly.

VALVE TAPPET CLEARANCE

Valve tappet clearance is the distance between the valve stem and the valve lifter when the lifter is on the low part of the cam. Tappet clearance is very important for smooth engine operation and maximum power. Overheating is less probable and the valves will have longer life if the tappet clearance is set properly. Proper tappet clearance will permit more efficient use of the fuel and much easier starting of the engine.

Tappet clearance is necessary because the valve stems are exposed to great heat and expand.

Figure 310 shows a cross section view of a valve and lifter with the proper tappet clearance. The valve shown at A is seated properly in the valve seat. The tappet clearance is shown at B and the valve lifter at C. This clearance, shown at B, is small but very important.

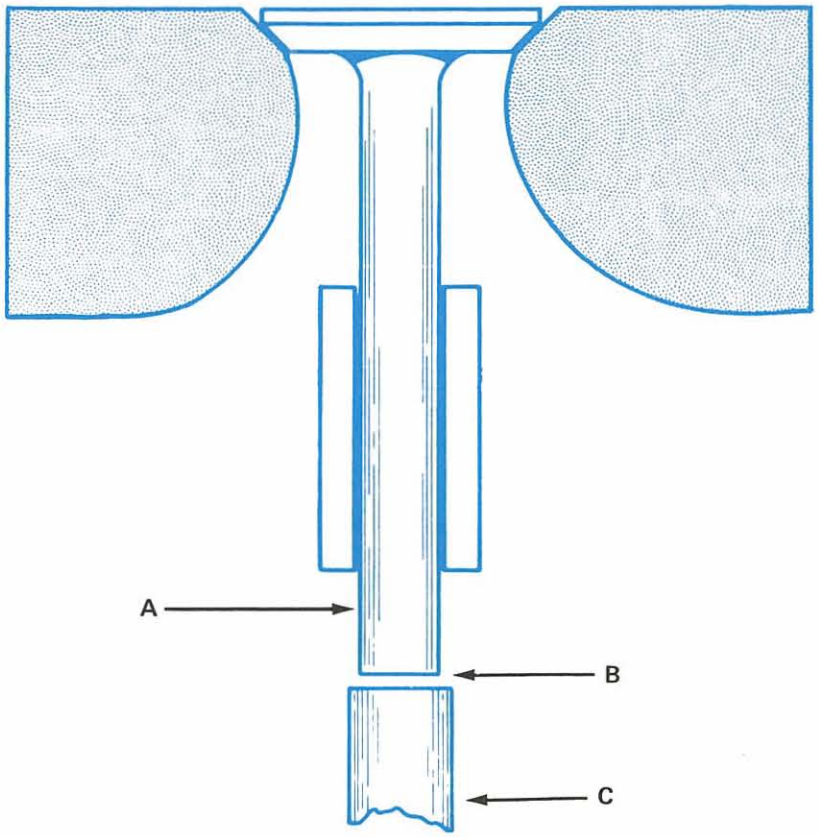


Figure 310

Because there is a heat difference between the intake and the exhaust valve the clearance should be a little more for the exhaust valve since it will have a tendency to expand more than the intake valve. Tappet clearance on most small engines can be set with the engine cold. The intake valve can be set at .007-inch the exhaust valve at .009-inch.

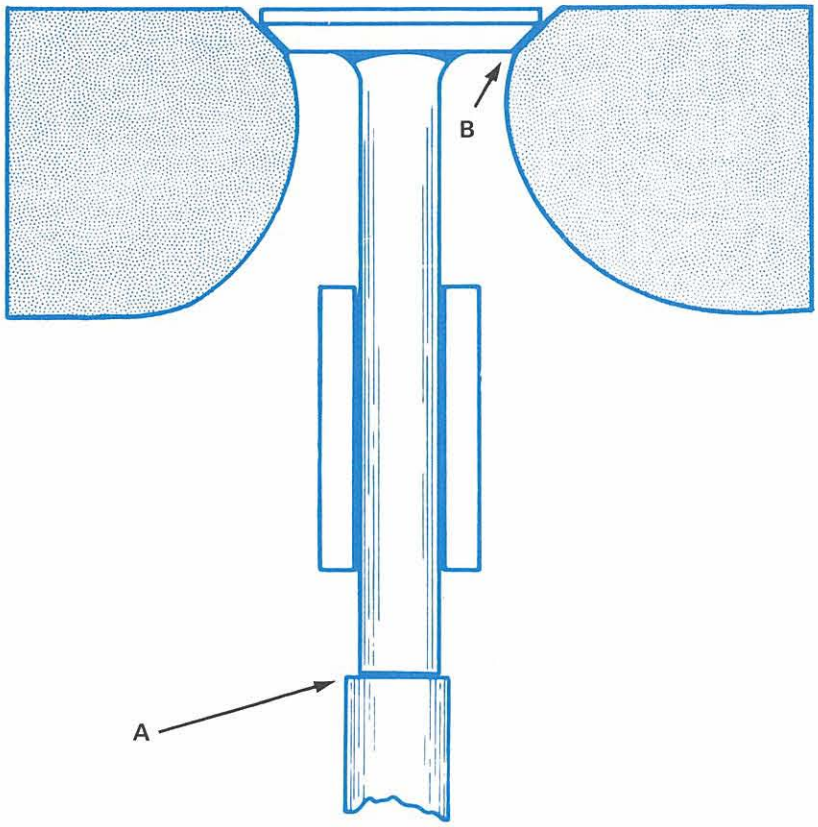


Figure 311

After the engine is in operation for a short time, heat will expand the valve stems so they will actually look more like the one shown in Figure 311. The distance, or clearance at A, will almost be closed and the valve will be seated as shown at B. If we started with tappet clearance of .007-inch on the intake valve and .009-inch on the exhaust valve we should have valve seating like the one shown in Figure 311 after the engine reaches its operating temperature.

Suppose this tappet clearance were inadequate as shown in Figure 312. When the engine reached its operating temperature the valve stem would expand. The lifter, shown at A, would be on the low point of the cam, which will not allow it to drop any lower. The valve spring forces the valve down until it contacts the lifter but there is no clearance at B. The valve is not closed as shown at C. This allows gases to escape. Little or no tappet clearance will throw the valves out of time causing them to open too soon or close too late for proper timing.

If there is too much tappet clearance there is a noisy delay in valve timing. The fuel-air mixture is late in coming into the cylinder during the intake stroke. Too much clearance in the exhaust valve will cause it to close too early, preventing all of the gases from being removed. Excess tappet clearance will cause the valves to close with a heavy impact that can cause them to break or crack. The lobe, or sloping part of the camshaft that raises the valve lifters, closes them gently when the proper tappet clearance is present.

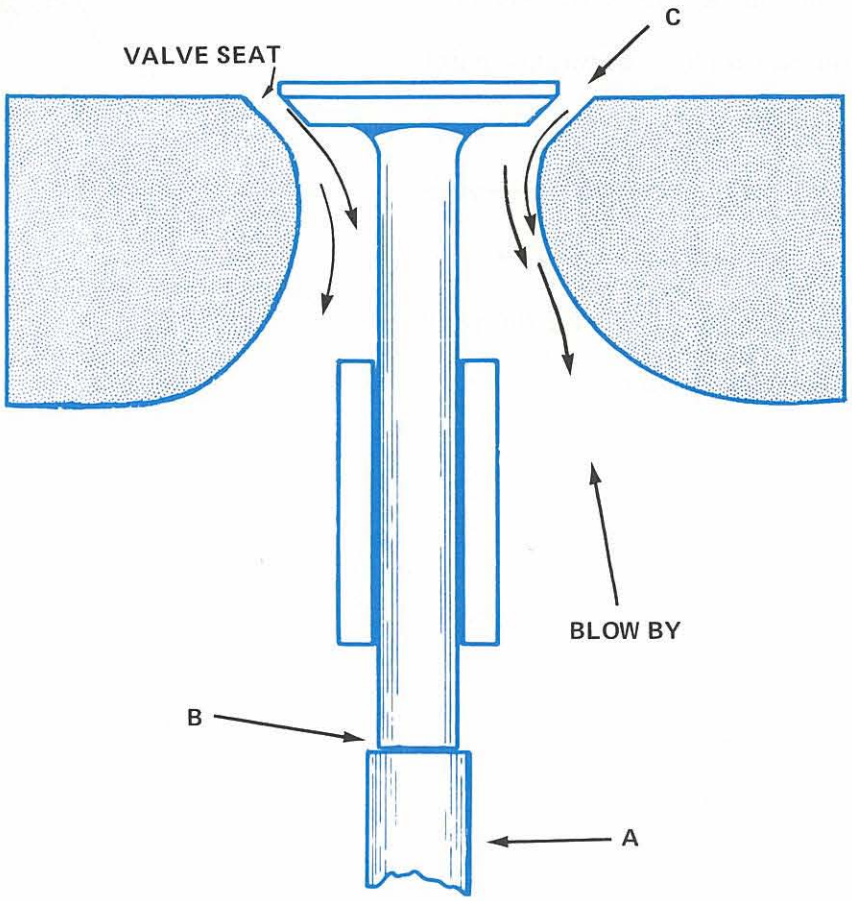


Figure 312

TAPPET CLEARANCE DESIGN

There are two methods used in most small engine design to obtain the valve tappet clearance. The most common is to grind off part of the valve stem. Another has an adjustable valve lifter. This adjustable lifter is used on some of the larger engines and on automotive designs.

The one most commonly used on small engines is shown in Figure 313. The valve, shown at A, is closed and the valve spring B is expanded to hold the valve down and closed. The valve lifter C is riding on the low part of the cam lobe shown at D. When the valve lifter is riding on the cam lobe, at this low point the valve tappet clearance, shown at E, should be at the maximum. As the valve wears and the seat is ground this tappet clearance will become smaller. To increase the clearance to the proper setting the valve stem can be ground to make it shorter.

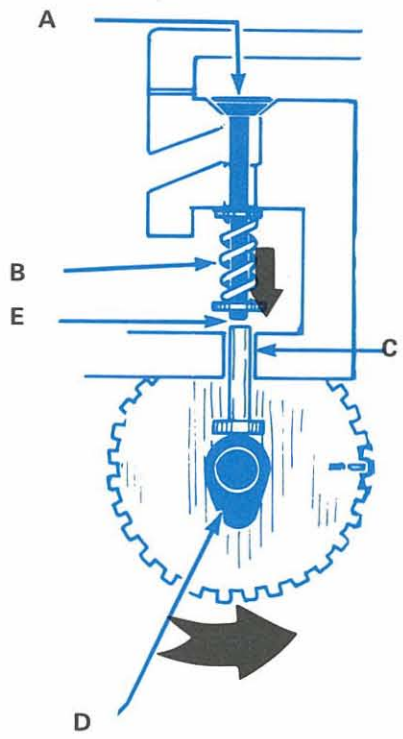


Figure 313

Another method of obtaining tappet clearance is shown in Figure 314. This method uses an adjustable tappet shown at A. The screw is held stationary by the lock nut shown at B. The screw at A can be adjusted to obtain the proper tappet clearance, shown at C, and the lock nut will hold it in place. This gives the same effect as shortening the valve stem by grinding.

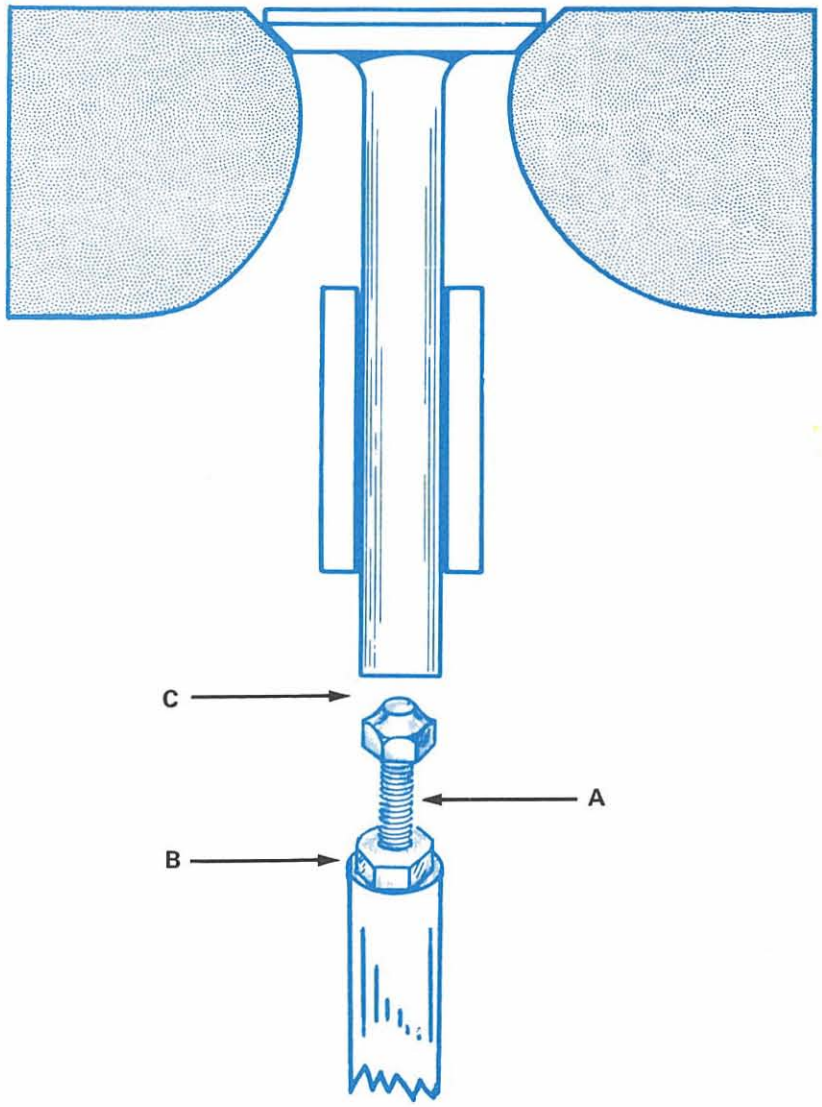
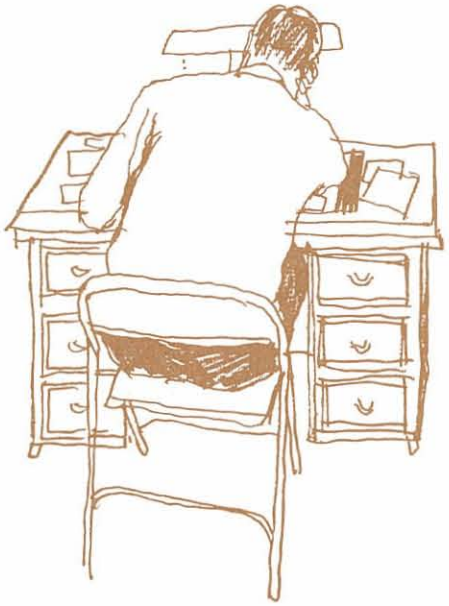


Figure 314

Most of the small engines under 5 horsepower will use the valve tappet design shown in Figure 313 and will require shortening of the valve stem to obtain the proper clearance. Just a little later we will go into more detail in making these adjustments.

Different engine manufacturers have different tappet clearance specifications that are given in their service manuals for individual engine size and models. However, as a general rule, most of the small engines you will be working with can be adjusted with a cold setting of .007 to .009-inch for the intake and .009 to .011-inch for the exhaust valve.



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. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

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- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
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EXAMINATION ON LESSON 31
FOUR CYCLE TIMING AND COMPRESSION TEST

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

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The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. When the piston is on the intake stroke, it creates a _____ above it. _____
   a. high pressure area
   b. vacuum
   c. neither of the above

2. The point when both valves are slightly open is known as valve overlap. _____
   TRUE
   FALSE

3. When the valve lifter is riding on the low point of the cam, the tappet clearance should be at its _____. _____
   a. minimum
   b. maximum
   c. makes no difference

4. The relationship of the piston to the valve is controlled by the timing gears. _____
   TRUE
   FALSE

5. On the power stroke, both valve lifters are riding on the _____ point of the cam. _____
   a. high
   b. low

6. For most small engines the intake valve clearance can be set at _____. _____
   a. .001″
   b. .003″
   c. .007″

7. The marks on a camshaft and the crankshaft gears are known as timing marks. _____
   TRUE
   FALSE

8. When the piston is traveling up on the _____ stroke, both valves are closed. _____
   a. intake
   b. compression
   c. power
   d. exhaust

(Continued on page 2)

9. Tappet clearance is necessary because the valve _____ expands. _____
   a. stem
   b. head
   c. seat

10. On the exhaust stroke the exhaust valve lifter is riding on the _____ point of the cam. _____
    a. low
    b. high

11 To increase the tappet clearance to the proper setting the valve stem can be ground to make it shorter. _____
    TRUE
    FALSE

12. Both the intake and exhaust valves are controlled indirectly by the location of the piston. _____
    TRUE
    FALSE

13. When the piston is traveling down on the power stroke, both valves are _____. _____
    a. open
    b. closed
    c. intake open, exhaust closed

14. The intake valve will generally have a little more tappet clearance then the exhaust valve. _____
    TRUE
    FALSE

15. When the piston is traveling up on the exhaust stroke, the intake valve is closed, and the exhaust valve is _____. _____
    a. closed
    b. open

16. For most small engines, the exhaust valve clearance can be set at _____ . _____
    a. .002″
    b. .004″
    c. .009″

17. On the compression stroke, both valves are riding on the high point of the cam. _____
    TRUE
    FALSE

18. Under normal conditions, poor compression can generally be traced to _____. _____
    a. valves
    b. rings
    c. head gasket
    d. all of the above

19. When the piston is traveling down on the intake stroke, the intake valve is open and the exhaust valve is _____. _____
    a. open
    b. closed

20. The piston location is directly related to the valve function at any given location. _____
    TRUE
    FALSE

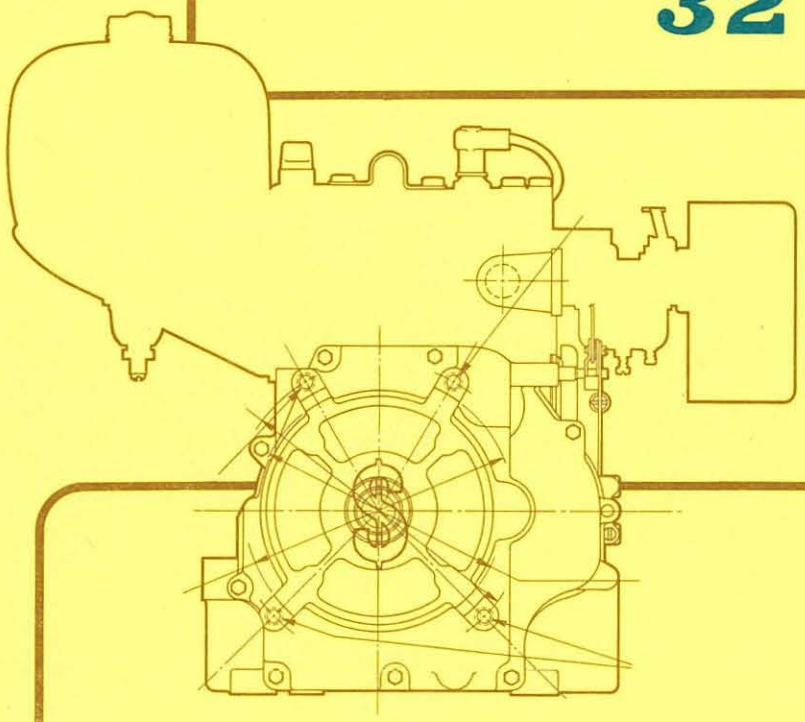
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

32



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CYLINDER HEAD AND VALVES

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REMOVING CYLINDER HEAD

First, remove the spark plug and carburetor. It will generally be necessary to remove the gas tank and other cowling or air deflector parts such as the ones shown in Figure 315. Some of these parts will be held in place with one or more of the head bolts holding the cylinder head to the block. On some engines these parts may have other things attached to them so it is necessary to study the assembly carefully before beginning to remove the parts as they must be replaced the same way they came off.

Use a socket wrench to remove the cylinder head bolts. On some engines these bolts are different lengths and it is important that the bolts be replaced in the same holes they were removed from.

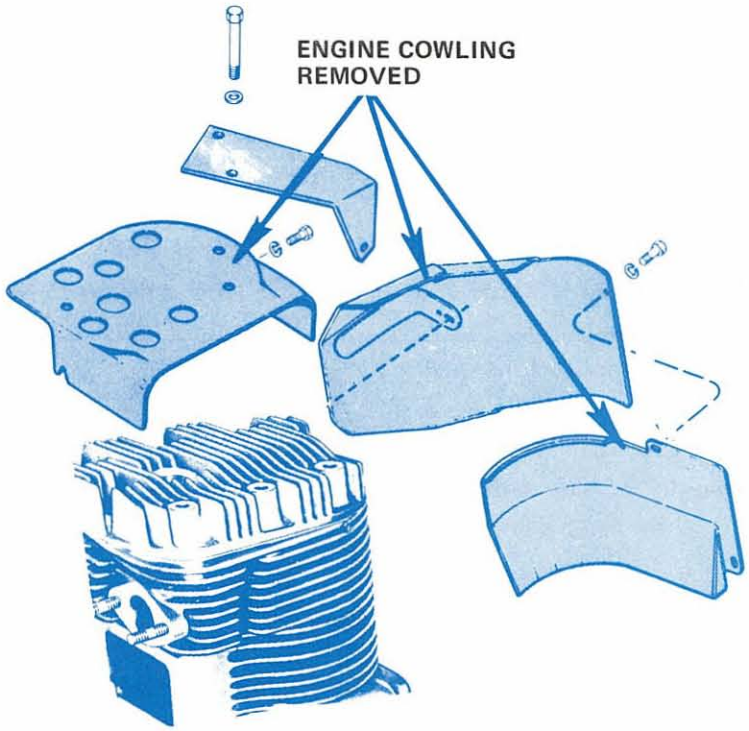


Figure 315

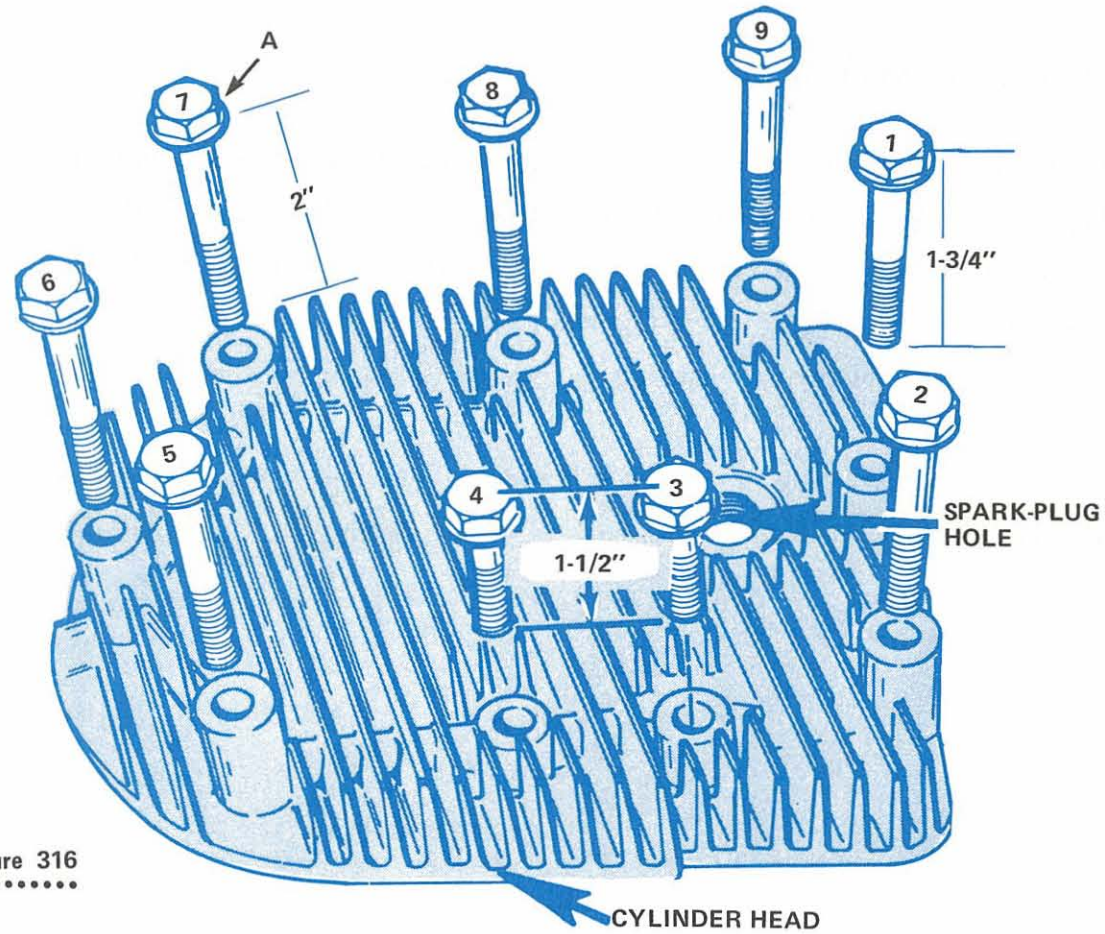


Figure 316

Figure 316 shows a typical example of the bolt lengths that may be used. The difference in length is generally due to the other parts that are attached to the engine with these same bolts. Engines designed for different applications may have different size bolts in the same place on identical engines. The bolt, shown at A, is longer than the others which would indicate a thicker piece would be attached to the engine between the bolt head and the cylinder head.

When replacing one of these bolts if you use one that is too short it would not have enough thread holding power and possibly would strip either the bolt or the cylinder block. If too long a bolt is used it will go to the bottom of the threaded part of the cylinder block without exerting any holding pressure on the cylinder head. This could cause a leaky head gasket at this point. The cylinder head is not threaded so if a bolt is too long it would force itself against the bottom of the threads and if you continued to turn it would strip out the threads in the block.

Different size and engine designs will also have different size and number of head bolts. Generally all head bolts will be the same diameter for any particular engine but the lengths may be different.

After all bolts have been removed the cylinder head and gasket can be removed. Sometimes it may be necessary to tap the head with a soft mallet if it wants to stick to the block. The gasket will usually come off stuck to the head or remain on the block. In the majority of cases, this gasket should be replaced with a new one so don't be afraid of damaging it in removal. If it comes off very easily it may have been installed only a short time and possibly can be reused.

After removing the head turn the engine crankshaft to bring the piston to T.D.C. with both the intake and exhaust valves closed. This is to prevent any foreign matter from falling into the area around the valve stem.

CLEANING CYLINDER HEADS

Clean the area around the cylinder head as shown in Figure 317. First brush off some of the rough deposits with a wire brush and then use a scraper to clean all carbon deposits from the head. Generally a heavy gauge putty knife, ground to a single angle, or a wide wood chisel will do a satisfactory job of scraping off the carbon deposits. Care should be taken with aluminum heads and blocks to prevent scratching and scarring the metal.

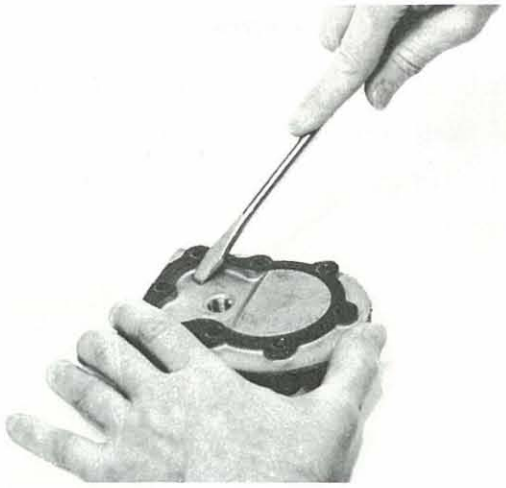


Figure 317

After all heavy deposits have been removed, clean with a wire brush to get off all possible remaining deposits. Pay particular attention to the area around the beveled edge of the spark plug hole and the two curved sections that fit just above the valves.

CLEANING CYLINDER BLOCKS

The top of the cylinder block should be cleaned, as shown in Figure 318, using the same tool. Clean all the top surface of the block and the top of the piston. Be sure the piston is at T.D.C. so carbon will not fall into the area of the piston and cylinder wall. Pay particular attention to the area around the valves and the tops of the valves. After all carbon has been scraped from the piston and head use a wire brush for final cleaning, then wipe clean with a cloth.

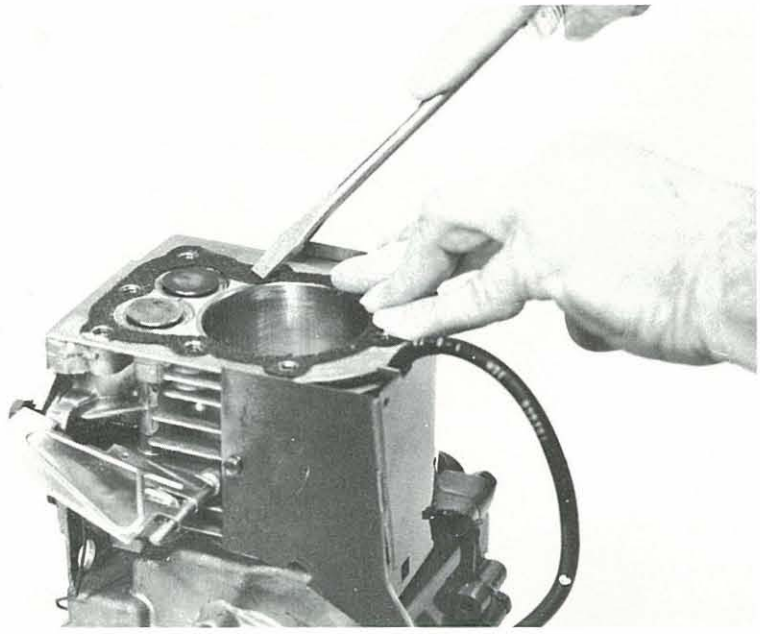


Figure 318

After all foreign matter has been removed, turn the crankshaft to raise each valve to its maximum height. Clean the area between the valve face and seat with a wire brush. Then inspect the valves for damage or wear.

REMOVING VALVES

In order to gain access to the valve spring and tappet area it is necessary to remove the carburetor and valve cover plate as shown in Figure 319. Generally you can inspect the valve and valve seat area without removing them. If they show very slight wear, they can often be lapped to bring back to good condition as we will cover later.

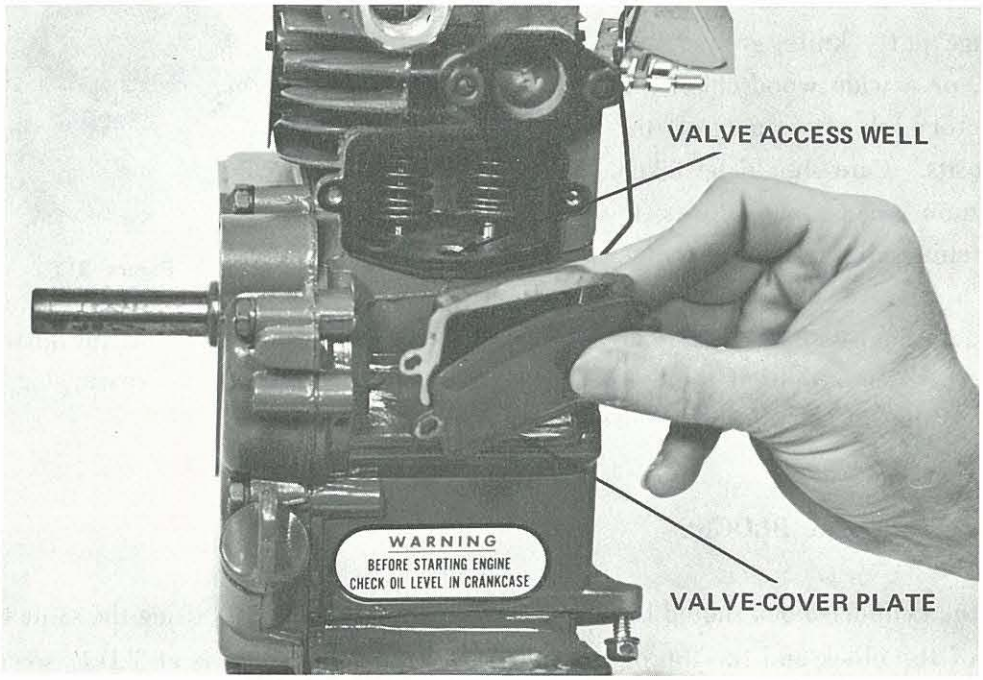


Figure 319

A valve spring compressor tool is almost necessary in order to release the valve springs. Sometimes the spring can be released by using screwdrivers and other tools to release the tension but it is neither practical or safe. There are a number of different types of valve spring compressor tools but they all use the same basic design. Pressure is exerted on the top of the valve and the bottom of the valve spring to release its tension. This allows the retainer to be free of pressure and easily removed.

Figure 320 shows a typical valve spring compressor. This is actually nothing more than a C-clamp with a fork on the end opposite the screw. First insert the fork part of the compressor tool just under the bottom of the spring as shown at A. Next line up the top screw head directly on top of the valve head and tighten the screw. This will compress the spring and release the retainer.

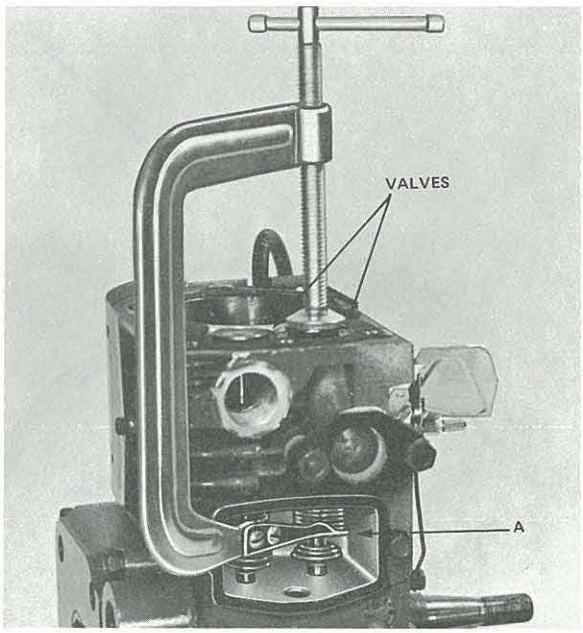


Figure 320

Once the spring is compressed the retainer will be released as shown in Figure 321. Earlier we studied the construction of the different designs of retainers. They may be either a pin, split collars or combination retainer and lock.

CAUTION

Do not reach in with your finger to retrieve the retainers. Get them out with a screwdriver, magnet or other tool. This spring is under very high tension and if the compressor tool were to slip it could cause severe injury.

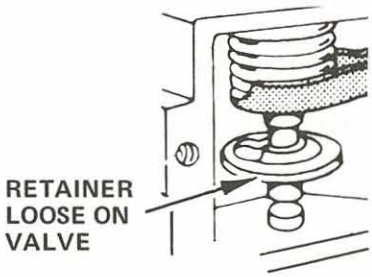


Figure 321

After the retainer has been removed, release the compressor tool. The valve can then be lifted straight out and the spring removed. Study the valve carefully to see whether it is the intake or the exhaust valve. Then make a note, whether it came from the left or right side. Remember the exhaust valve will generally be a lighter color due to the burnt exhaust gases.

After the valve has been removed, match it up with its spring and keep them separate. These springs should not be mixed as some engines may have an exhaust spring heavier than the intake spring. When at all possible, replace them in the same position as they were originally.

INSPECTING VALVE ASSEMBLIES

The condition of the valves can tell a great deal about the condition of the engine. Since heat has a very deteriorating effect on metal, the intake valves generally do not show as much wear or damage as the exhaust valves. The intake valves receive some cooling effect from the fuel-air mixture going into the cylinder.

Intake valve trouble is often caused by the use of stale or a poor grade of fuel. Gum and deposits will begin to build up on the neck of the valve in the area shown at A in Figure 322. Since the valve stem moves up and down inside the valve guide, shown at B, the gum deposits on the valve stem will make the valve tend to stick instead of moving up and down freely. This will cause the valve to stick and eventually cause burning.

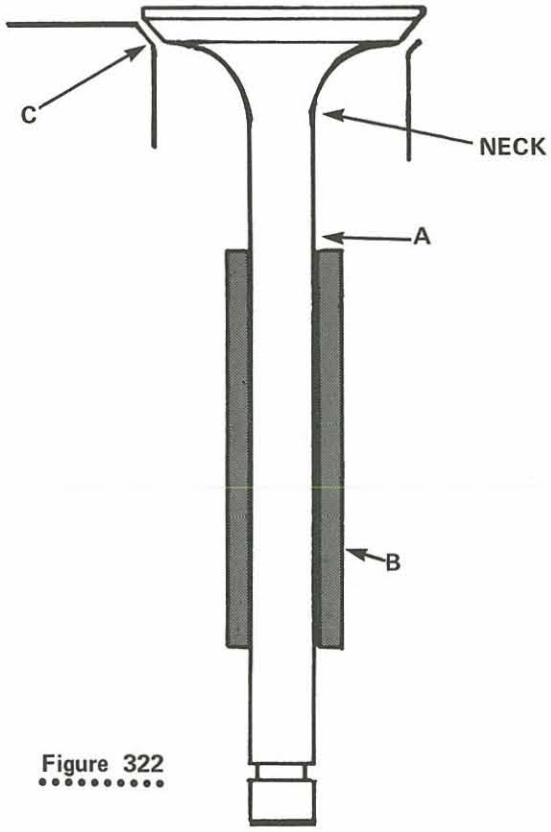


Figure 322

Another cause of intake valves sticking and burning is a worn or damaged valve stem or guide. The guide can also become out of round. These conditions permit leaking oil to enter into the upper end of the valve guide and eventually around the valve seat area. This oily condition will come from a breather hole near the bottom of the valve stem. This hole goes directly to the crankcase.

Exhaust valves operate under very high temperature. For cooling they depend on heat dissipation through the valve seat shown at C. Heat is then dissipated through the cooling fins. Anything that will cause the engine to run warmer than normal will effect the life of the valves. Insufficient air circulation around the cooling fins, caused from grass or other foreign matter around the shrouds, will cause the engine to run hot and greatly reduce the life of the valves.

Excessive tappet clearance will not allow the valve to open enough to permit the heat and exhaust gases to escape fast enough. Improper timing will cause the valve to open or close too soon. This prevents all the gases from escaping and causes an excess of heat. For these reasons, exhaust valves are more likely to show wear or failure before the intake valves. To overcome part of this, the exhaust valves are made of a heat-resistant steel. Weak valve springs will sometimes prevent the valve from closing properly. Valves in 4-cycle engines can cause many problems and are responsible for a large part of engine failure and poor operation.

VALVE CONDITION AND CAUSE

You can generally look at the condition of a valve and determine what caused it to fail. By close examination there will be one or more signs that will tell you what problems exist.

Evidence of gum and varnish deposits would indicate the use of low quality, or stale fuel or lubricating oil. Worn or loose valve guides will permit lubricating oil and other deposits to accumulate around the valve neck and seat. Poor crankcase ventilation and operating with an excessively rich fuel-air mixture will leave extra gum deposits.

Valve burning will often be caused from a sticky valve stem not running free in the guide because of gum deposits. Insufficient tappet clearance will not permit the valves to open the proper distance and weak valve springs will not close the valves tight enough. A clogged muffler will cause back pressure and not allow exhaust gases to escape fast enough.

Valve springs can be checked by comparing them with a new one. Figure 323 shows the wear points.

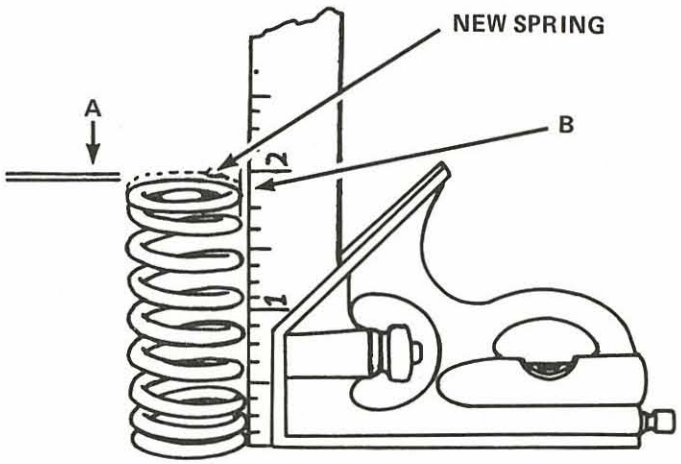


Figure 323

The difference in spring lengths should not be more than 1/16-inch as shown at A. They should be square at top and bottom and not more than 3/16-inch difference as shown at B. Valve springs seldom cause trouble unless the engine is very old or, if they have been bent or sprung from improper removal or replacement.

VALVE GUIDES

Generally valve guides cause very little trouble and before any repair or replacement is considered, it would be well to inspect the other parts of the engine for excess wear and condition.

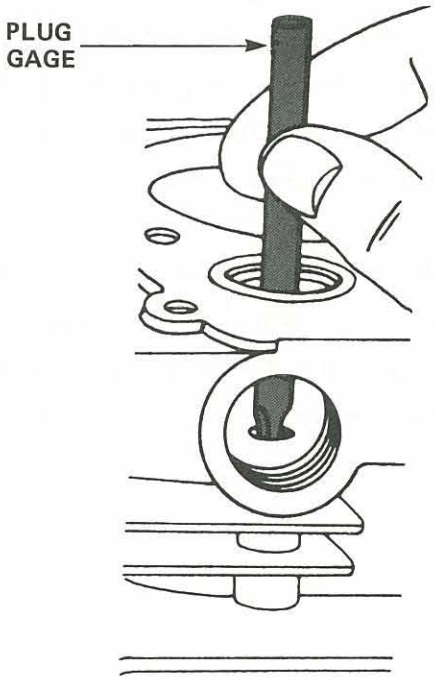
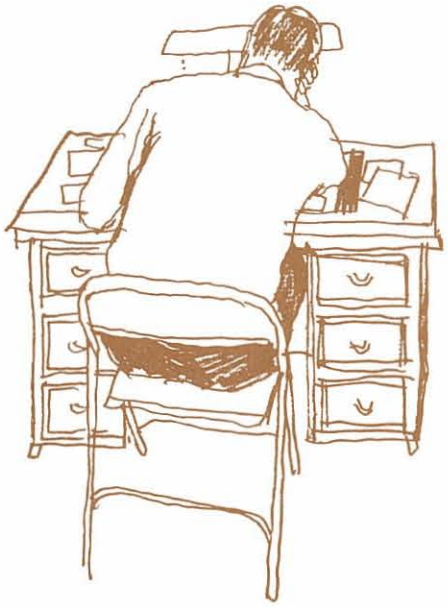


Figure 324

In order to do complete rebuilding of the valve assembly it is necessary to have a considerable amount of equipment such as different size reamers and gauges and sometimes a special arbor press for removing and replacing the guides is necessary. Excess valve guide wear can be checked with a plug gauge as shown in Figure 324. After the guide has been cleaned, the plug gauge should make a snug fit if the guide is in good shape. There should not be more than about .005 to .007-inch difference between the guide and the diameter of the valve stem.

After some experience with different small engines, you will soon be able to feel the amount of acceptable guide wear by moving the valve stem back and forth with your fingers. Some engines do not have valve guides. They are checked the same way and, if wear is indicated, the hole must be reamed oversize and a replacement valve guide installed. It is then reamed to fit the valve stem.

Some valve guides must be driven out from the bottom and some can be driven out from the top. With careful inspection of the engine you can determine which way to remove it. A replacement guide is nothing more than a sleeve driven into a hole with a very tight fit.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 32
CYLINDER HEAD AND VALVES

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NAME _____ Student No. _____
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ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Valve burning will often be caused from sticky valve stem not running free in the guide because of gum deposits. _____
   TRUE
   FALSE

2. If the valves and valve seat areas show only slight wear, they can be lapped to bring them back to good condition. _____
   TRUE
   FALSE

3. Excessive valve guide wear can be checked with a _____. _____
   a. feeler gauge
   b. plug gauge
   c. ruler

4. _____ valve trouble is often caused by the use of stale or poor grade fuel. _____
   a. intake
   b. reed
   c. neither of the above

5. Since the cylinder head is of uniform thickness, all head bolts will be the same length. _____
   TRUE
   FALSE

6. In order to gain acess to the valve spring area, it is necessary to remove the carburetor and _____ on most small engines. _____
   a. crankcase
   b. head
   c. valve cover plate

7. Evidence of gum and varnish deposits would indicate the use of low quality or stale fuel. _____
   TRUE
   FALSE

8. After the cylinder head is removed, all carbon deposits should be removed. _____
   TRUE
   FALSE

(Continued on page 2)

9. The difference in valve spring lengths should not be more than _____. _____
   a. 1/32″
   b. 1/16″
   c. 1/8″

10. The exhaust valves generally do not show as much wear or damage as the intake valve. _____
    TRUE
    FALSE

11. All small engines have valve guides. _____
    TRUE
    FALSE

12. When cleaning the top surface of the cylinder block, the piston should be at _____. _____
    a. bottom dead center
    b. top dead center
    c. makes no difference

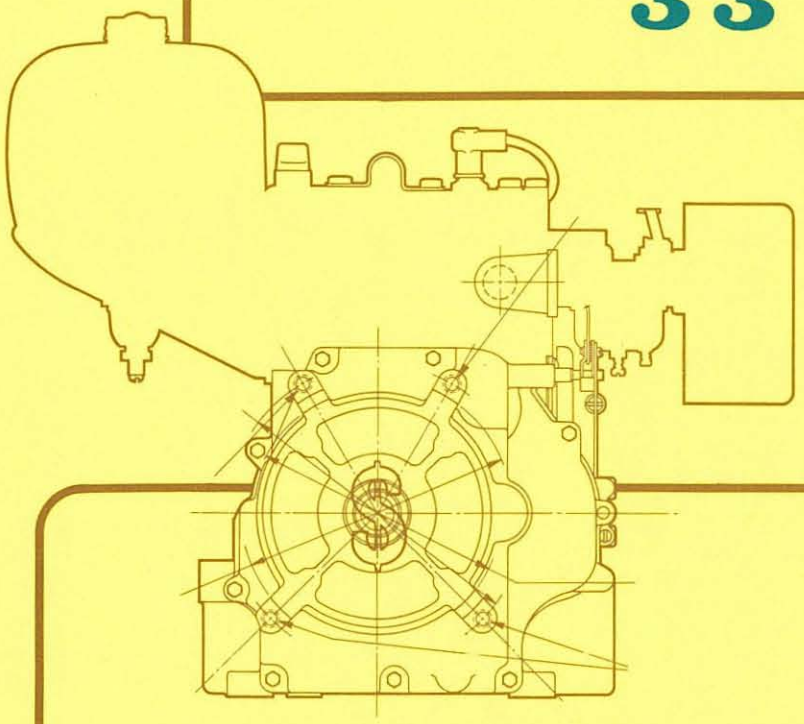
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

33



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...and let's find out all about -- **VALVE REPAIR**

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GRINDING VALVES

Valve grinding is often not necessary each time an engine is given a minor tune-up. In many cases the valve condition can be corrected by lapping the valves which we will cover later. When installing new valves only lapping is necessary. Valve grinding requires a special machine designed to produce the desired angle on the valve face with a grinding wheel. Both the valve and the grinding wheel must be turning. Figure 325 shows a typical valve grinding machine set up for grinding the valve face. The valve A is held in place in the grinder chuck shown at B. This chuck holds the valve and is turned by an electric motor that turns the valve at a very slow speed. The chuck is adjustable in a circular motion to give the correct bevel to the valve face. This adjustment has a gauge that can be set to give the amount of bevel degree desired for the valve face.

The grinding wheel motor, shown at C, is mounted on a sliding base which allows it to be moved laterally back and forth with the control handle shown at D. Another control handle, shown at E, moves the chuck in and out so the valve face can be brought into contact with the grinding wheel.

After the valve has been positioned in the chuck and set at the proper angle, bring the valve to a position just before it touches the wheel. Move the wheel back and forth in a lateral motion to be sure all adjustments are correct. Then turn on the motors controlling both the grinding wheel and the valve chuck. Move the wheel toward the valve face. Turn the control adjustment to move the valve face closer to the wheel until you see sparks just begin to appear. Take very light grinds and repeat grinding. Check face of valve carefully each repeat grinding to be sure it is grinding all the way around the valve face.

It takes a considerable volume of work to warrant the investment of a valve grinder since only a small percentage of the engines will require a complete valve job. Many shops that do not have the volume of business to justify a valve grinder have it done at an auto repair shop. The same grinder, set at the proper angle, will do the job.

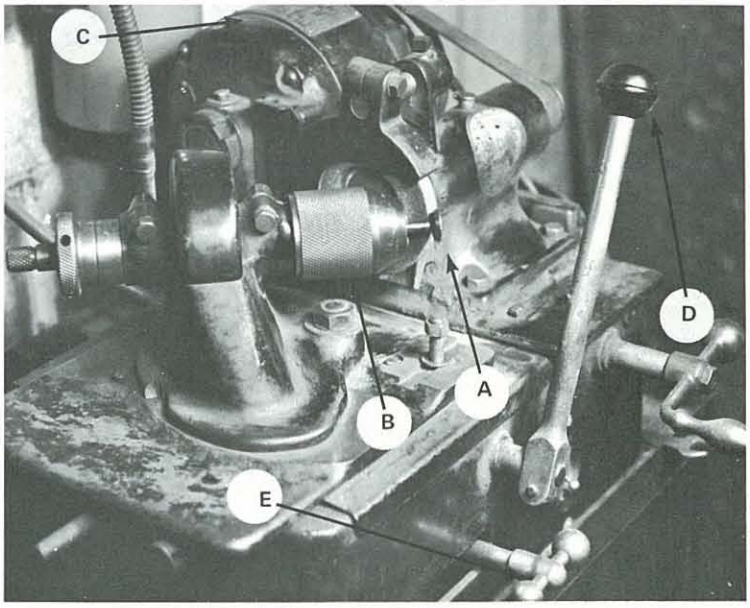


Figure 325

VALVE SPECIFICATIONS

Typical valve specifications are shown in Figure 326. If the margin, shown at A, is less than 1/64-inch the valve should not be used. After valves have been ground several times the face, shown at B, increases in width and the margin decreases. The margin should never be allowed to be less than 1/2 the thickness of a new valve. If the margin is too small, replace the valve with a new one. Most all small engine valves are ground at an angle of 45 degrees as shown at C.

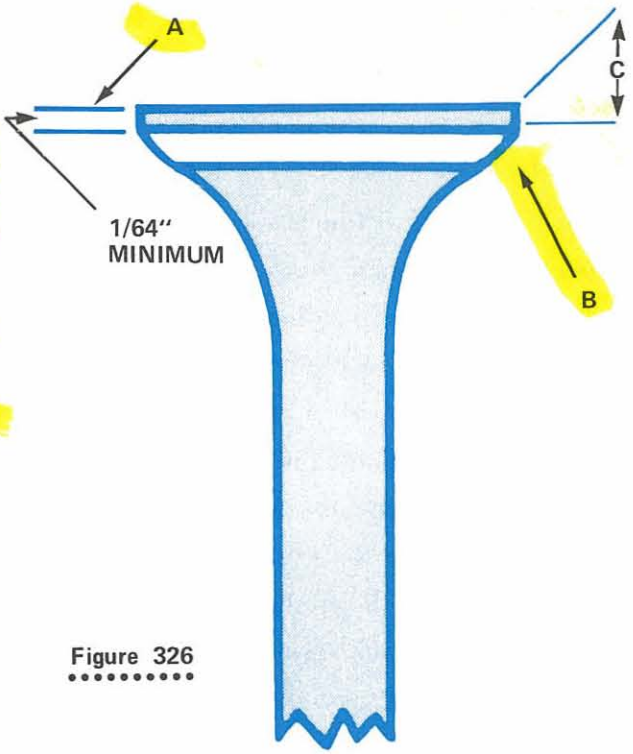


Figure 326

GRINDING VALVE SEATS

In order to get a tight seal between the valve seat, it is necessary to grind the valve seat each time the valve face is ground. There are special tools available at automotive supply houses for grinding valve seats. Figure 327 shows one type that uses an abrasive disc that is replaceable. The abrasive cutter, shown at A, is set at 45 degrees and can be used for reseating either hard or soft valve seats. Some valve seats have a replaceable insert that is made of a very hard metal. We'll cover these replacement seats later.

There is a pilot shaft, shown at B, that fits directly into the valve guide. When the cutter is lowered into the valve seat it is in the same position as the valve and held at a true right angle. The abrasive cutter should be dipped in kerosene to prevent the abrasive from clogging and allowing it to cut free. You can use either a speed wrench or bit brace for turning the cutter. Rotate the cutter in both directions when grinding.

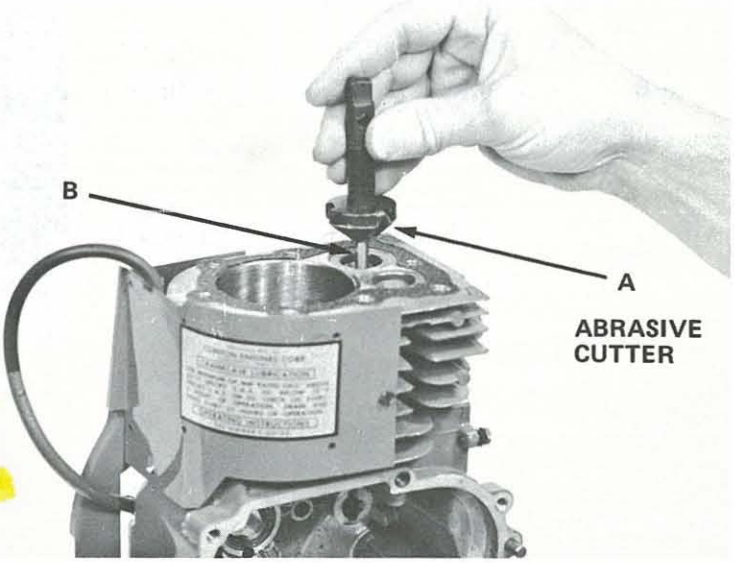


Figure 327

Another type of cutter is shown in Figure 328. This uses a blade cutter made of very hard metal and can be turned in only one direction. It is not turned back and forth as with the abrasive cutter. Even though the blade is made of a very hard metal, it is not hard enough to work with some of the special hardened valve seat inserts that are used on some engines.

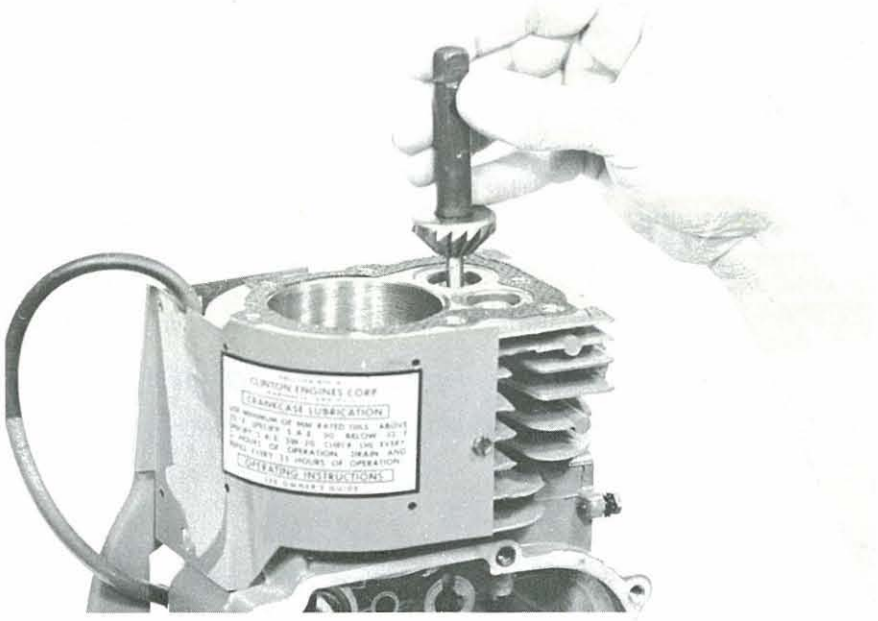


Figure 328

While grinding the valve seat, stop frequently to see what progress is being made. Valve seats should be ground no more than is absolutely necessary. When the valve seat is properly ground, it should look like the one shown in Figure 329. The seat should be from 3/64-inch to 1/16-inch in width as shown in A. The ground surface should be even and the same distance all the way around the face of the seat.

When the valves and the valve seats have been ground too many times, the valve will rest too deep in the block. As the valve is lowered by grinding of the face and seat, it is necessary to remove metal from the bottom of the stem in order to maintain the proper tappet clearance.

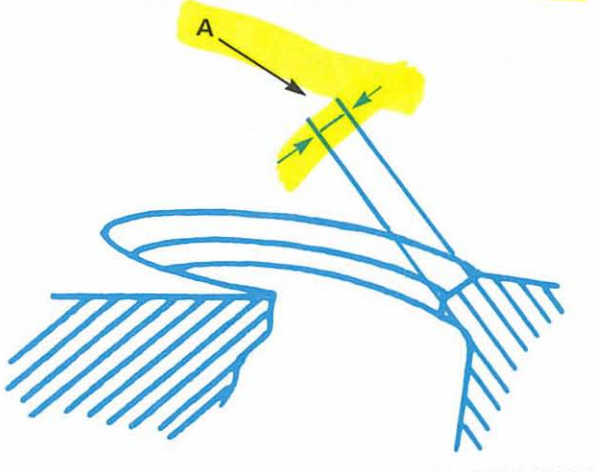


Figure 329

A good guide to use in determining whether the valve has been ground too much is to compare it with a new one. If over half of the metal from the lock groove to the end of the valve has been removed to get the proper tappet clearance it would indicate either a new valve was necessary or a new valve seat. Generally a new valve seat is required, however, sometimes an excess of metal is removed when grinding valves by inexperienced mechanics and it will cause them to require too much metal to be removed from the end of the stem.

REPLACEABLE VALVE SEATS

Many engines in general use today have provisions for replacing valve seats if they are worn too badly to be reground. This procedure is not recommended as it takes a considerable amount of time and special tools. Generally when an engine reaches this condition there are other parts of it that will be completely worn out. The short block method of repair, which we will cover later, would be the best repair procedure to follow.

LAPPING VALVES

Lapping the valve face to the valve seat is actually the process of putting on a final finish between these two surfaces. After valves have been ground they should always be lapped to get the best possible seal between the valve and the seat. New valves or valve seats should also be lapped. Often a complete valve grinding job is not necessary and the condition can be corrected by a simple lapping job.

The first step in lapping the valves is to remove the valve springs and keepers. Starting with either the intake or the exhaust valve, turn the crankshaft so the valve lifter is at its lowest point. Check to make sure there is a valve tappet clearance, otherwise the valve will not contact the seat.

Valve grinding compound comes in three grades; fine, medium and coarse. Generally fine and medium are all that are necessary for average work. This compound comes in small cans and is available from most all automotive supply houses. If you have reground the valves or are installing new valves or seats, it may be necessary to start lapping with a coarse grade of compound, then medium, and finish with a fine grade.

Apply a thin coat of lapping compound to the valve face using either coarse or fine grade. Insert the valve in the cylinder block, making sure it is the proper valve. Using a valve lapping tool, as shown in Figure 330, apply slight pressure and rotate back and forth. Do not turn continuously in one direction. The lapping tool has a rubber suction cup that will stick to the valve. It helps attach itself to the valve if you moisten the rubber cup.

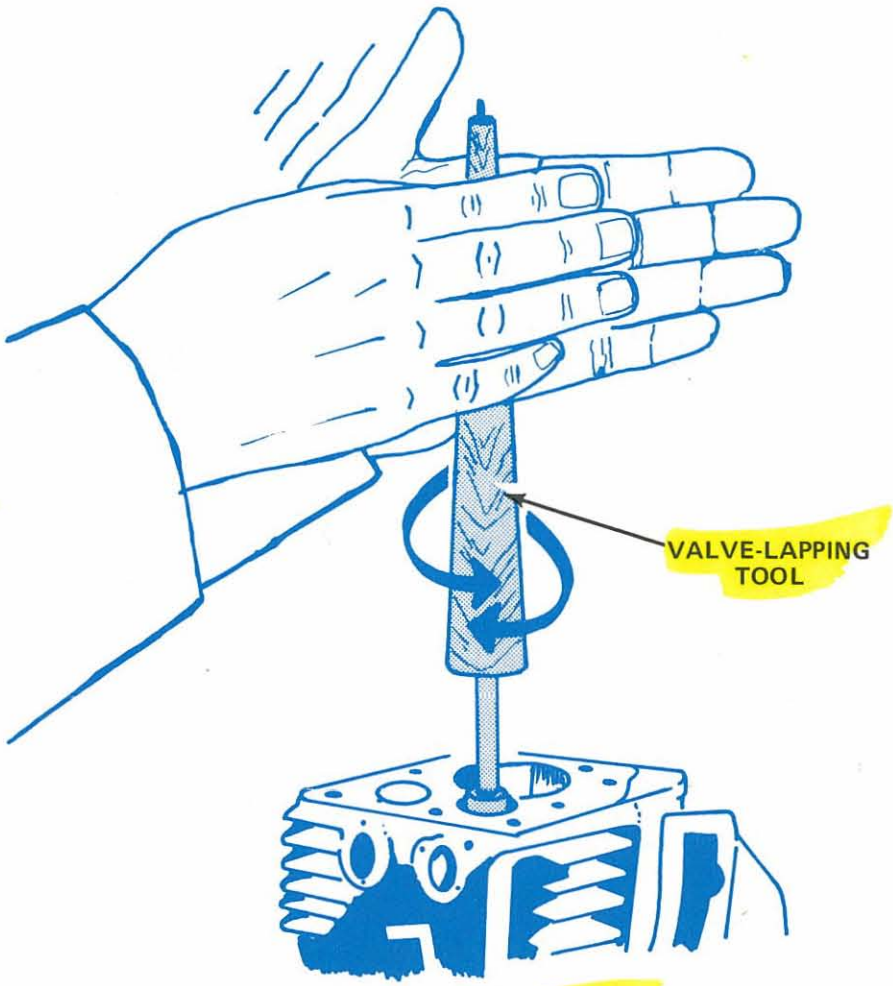


Figure 330

Be careful when lapping valves not to use an excess of compound. None of the compound should be allowed to go down into the valve stem area. It is very abrasive and will cause damage.

After lapping 25 or 30 times, remove the valve and wipe both the valve and the seat clean with a cloth. Check the valve carefully for results. You should begin to show a shiny ring around the face of the valve as shown in Figure 331. Continue lapping the valve until this ring covers about one-half of the face. It should be even all the way around the face. As soon as you have reached this point, wipe the valve and seat clean and lap the valve with a fine grade compound. If the valves are in fairly good condition, you can start with a fine grade compound.

If you do not show any cutting action when lapping, recheck the valve tappet clearance. If the valve is riding on the lifter it will not allow it to contact the face. It may be necessary to grind off a small amount from the valve stem.

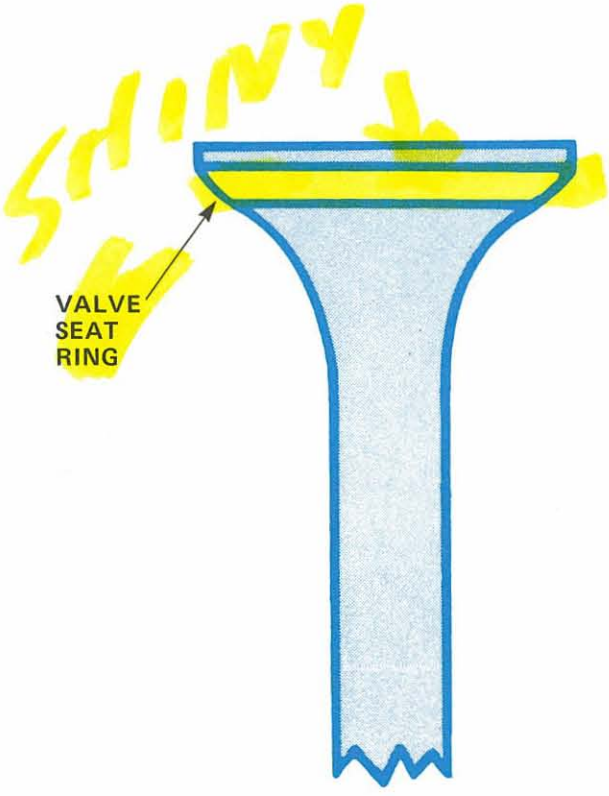


Figure 331

VALVE TAPPET ADJUSTMENT

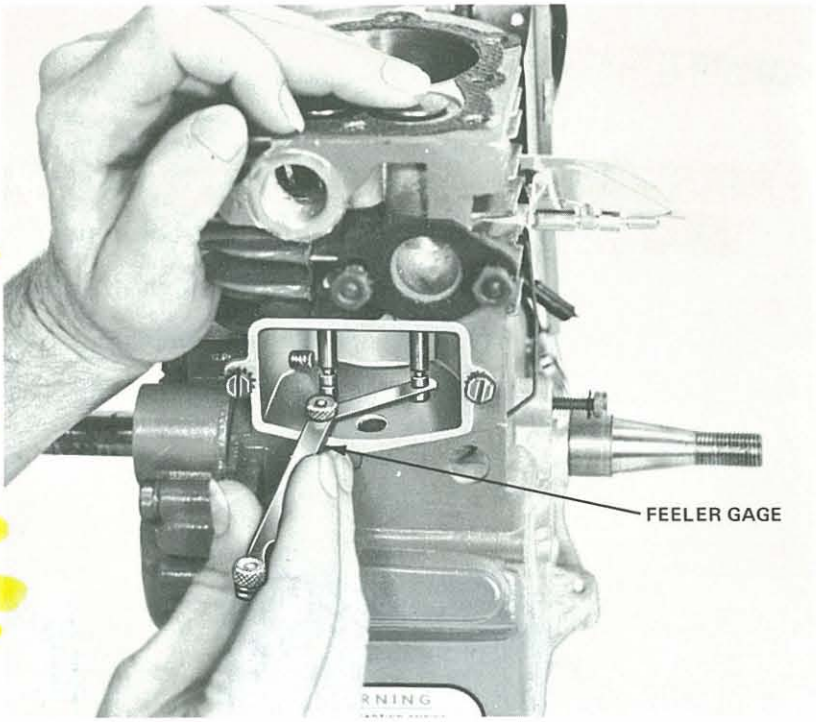


Figure 332

After the valves have been lapped and all lapping compound removed, the tappet clearance can be adjusted. If the engine has no valve tappet adjusting screw, like the one we covered earlier, it will be necessary to grind the valve stem to get the clearance. Clean the valve and apply a small amount of oil to the stem and hold it down against the valve seat as shown in Figure 332. Use a .007-inch feeler gauge for the intake valve and a .009-inch for the exhaust valve to check the clearance. If you have ground or lapped the valves this space is reduced and the valve stem very possibly is hitting the lifter. As you try to insert the feeler gauge, you can feel the valve head lift up.

Remove the valve and take a very light grind off the end of the stem. Be sure to grind square. It is best to use a "V" block or other fixture to hold the stem at right angles to the grinding wheel. Put the valve back in and check with a feeler gauge. If the valve still raises when you insert the gauge, take another light grind. Continue grinding the valve stem, being careful to remove only a very slight amount each time. Check after each grind until the feeler gauge just slips in between the valve stem and the lifter without lifting the valve head.

Make the tappet clearance adjustment on one valve at a time until you have the correct setting. After one is complete, go on to the other. It is very important to grind only a small amount each time. If too much is taken off, it will be necessary to replace the valve with a new one. Be sure the lifter is riding on the lowest point of the cam when making these adjustments. After both valves have been adjusted, replace the springs and keepers. Be sure the valve cover plate is clean and the gasket is good before installing.

INSTALLING CYLINDER HEADS

There are three things to consider when tightening the cylinder head bolts. The bolt location is important since some may be longer than others. If a long bolt is used in one of the locations requiring a short bolt, the threads could be stripped while trying to tighten it. If a short bolt were used in a position requiring a long bolt, the threads may be stripped because there may not be enough thread to get adequate holding power. As mentioned earlier, it is important that these bolts be replaced in their proper location.

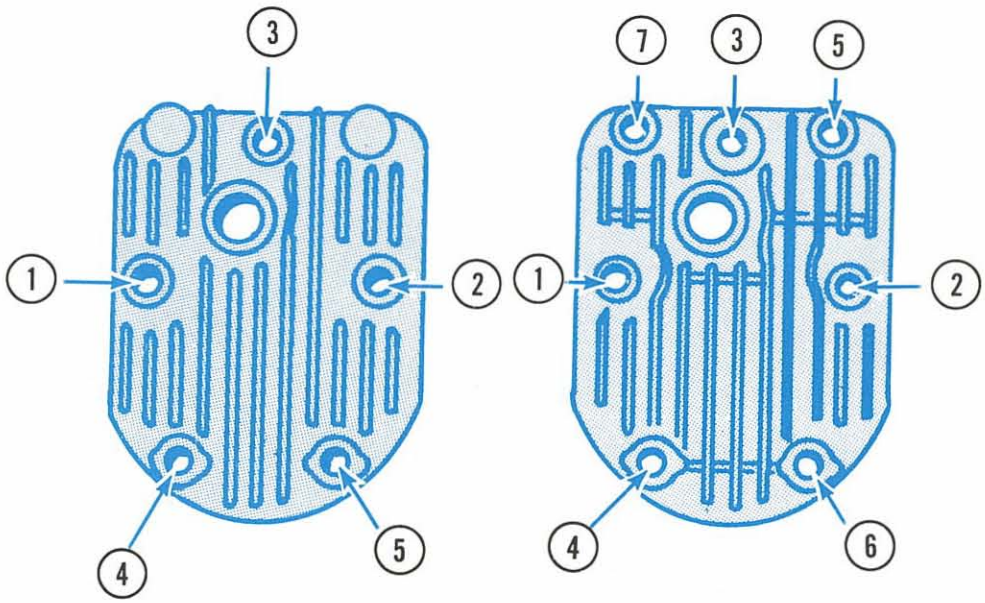


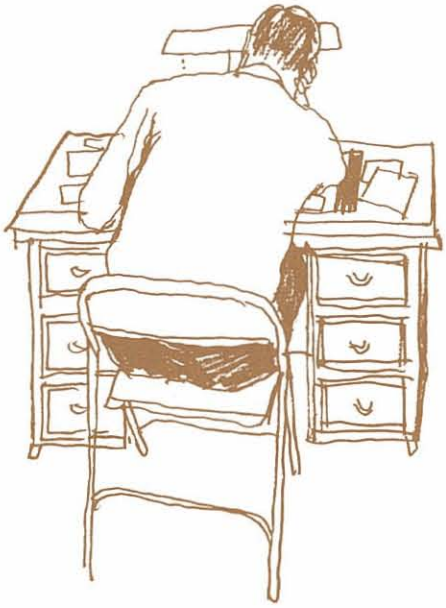
Figure 333

The recommended method of tightening head bolts is to work back and forth across the head and not go from one bolt to the next. Figure 333 shows the tightening sequence of two typical heads. Different engines may have slightly different locations, however, the basic principle of tightening across from each other would remain the same. Uneven tightening of the head bolts can cause warping of the cylinder head.

The amount of torque depends on the size of the head bolts, however, most small engines up to 5 horsepower should have 15 to 20 foot pounds of torque on aluminum blocks and 20 to 25 foot pounds on engines having cast iron blocks. When torqueing the head bolts it is a good idea to go around at least two times.

As a general rule, if you do not have a torque wrench, you can tighten the head bolts just snug with a small wrench using only about a 6-inch leverage. After they are all tight, use a wrench with a larger leverage and give each bolt another 1/4-inch turn.

Before installing the head, match the head gasket up with either the head or the block to be sure the bolt holes all line up. The design of most head bolts will not allow the holes to line up if the gasket is installed upside down. Some repair men think it best to recheck the tightness of the head bolts after the engine has been run a few minutes. This is a good idea if you are not using a torque wrench.



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Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

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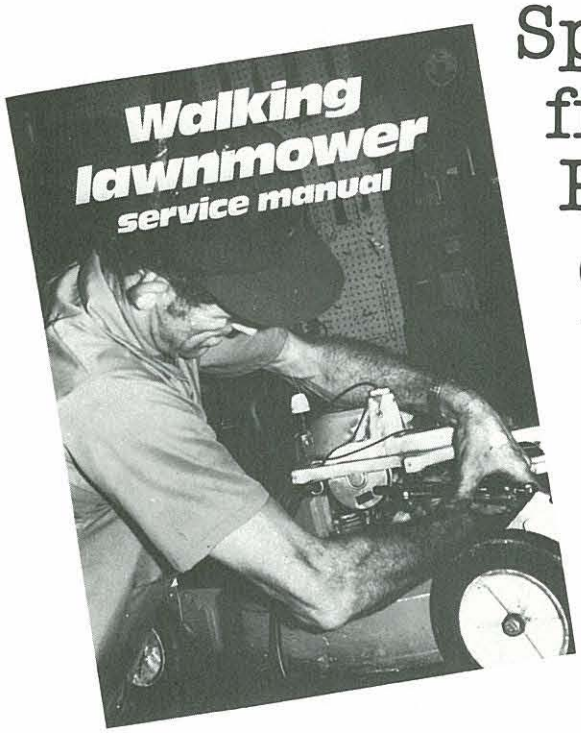

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EXAMINATION ON LESSON 33
VALVE REPAIR

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INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Valve clearance is checked with a _____. _____
   a. feeler gauge
   b. cylinder gauge
   c. ruler

2. The amount of torque for the head bolts on most small engines should be 20-25 foot pounds on cast iron block and 15-20 foot pounds on aluminum blocks. _____
   TRUE
   FALSE

3. As the valve is lowered by grinding off the face and seat, it is necessary to remove metal from the _____ in order to maintain the proper tappet clearance. _____
   a. margin
   b. seat
   c. stem

4. New valve or valve seats should always be lapped. _____
   TRUE
   FALSE

5. The recommended method of tightening head bolts is to go from one bolt to the next around the head. _____
   TRUE
   FALSE

6. After the valves have been ground several times, the face increases in width and the _____ decreases. _____
   a. tappet
   b. lapping
   c. margin

7. _____ the valve face to the seat is a process of putting on a final finish between the two surfaces. _____
   a. lapping
   b. stemming
   c. neither of the above

(Continued on page 2)

8. Uneven tightening of the head bolts can cause warping of the cylinder head. _____
   TRUE
   FALSE

9. If the _____ of the valve is less than 1/64 inch, the valve should not be used. _____
   a. stem
   b. margin.
   c. head

10. In order to get a tight seal, it is necessary to grind the valve seat each time the face is ground. _____
    TRUE
    FALSE

11. In many cases the valve condition can be corrected by lapping the valve. _____
    TRUE
    FALSE

12. Most all small engine valves are ground at an angle of _____. _____
    a. 28°
    b. 36°
    c. 45°

13. After the valves have been ground, they should always be lapped to get the best possible seal. _____
    TRUE
    FALSE

14. When lapping valves, always turn continuously in one direction. _____
    TRUE
    FALSE

15. When the valve seat is ground properly, it should be from _____ to _____ in width. _____
    a. 1/8″ to 1/4″
    b. 3/64″ to 1/16″
    c. 1/16″ to 1/4″

16. In lapping valves, the valve lifter should be on the _____ point on the cam. _____
    a. lowest
    b. highest
    c. neither of the above

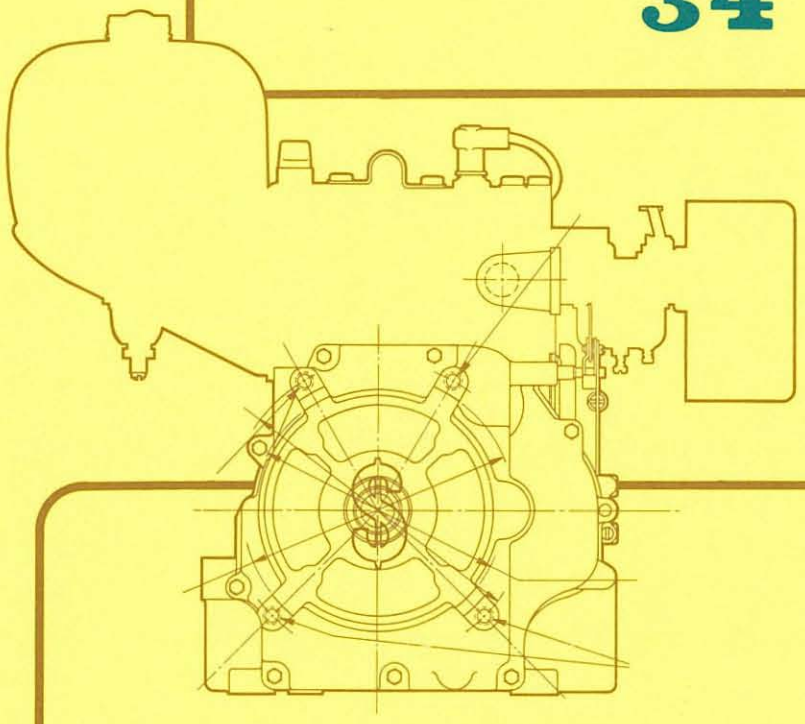
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

34



TURN THIS PAGE

...and let's find out all about --

PISTON AND ROD REMOVAL

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REMOVING 4-CYCLE PISTON AND ROD ASSEMBLIES

There are several steps necessary before you can remove the piston and rod assembly. The basic steps necessary apply both to vertical and horizontal crankshaft engines. The very first thing is to start with a clean engine. Not only is it easier to work on a clean engine, but when you begin getting into the inside of the engine it is very necessary to keep it free of foreign matter.

Drain the engine oil, remove the engine from the equipment if necessary. When working on most lawnmowers and other equipment it is not necessary to remove the engine from the equipment when working on horizontal shaft engines. The vertical shaft engines used on most rotary lawnmowers generally have to be removed in order to get inside the engine. Figure 334 shows a typical horizontal shaft engine with the drain plug shown at A and the filler plug shown at B.

Some makes of engines will have two drain plugs and two filler plugs. This is to accommodate different engine applications. The position it is to be used in with the equipment it is driving may interfere with one of the drain or filler plugs. In some applications it may be necessary to drain from one side and fill from the other.

When draining oil from a 4-cycle engine it is always a good idea to remove the filler plug while draining, so the drain will flow smooth. It is also good to tilt the engine slightly in the direction of draining so all the oil will drain out, otherwise there is a possibility of some oil remaining in the bottom of the crankcase.

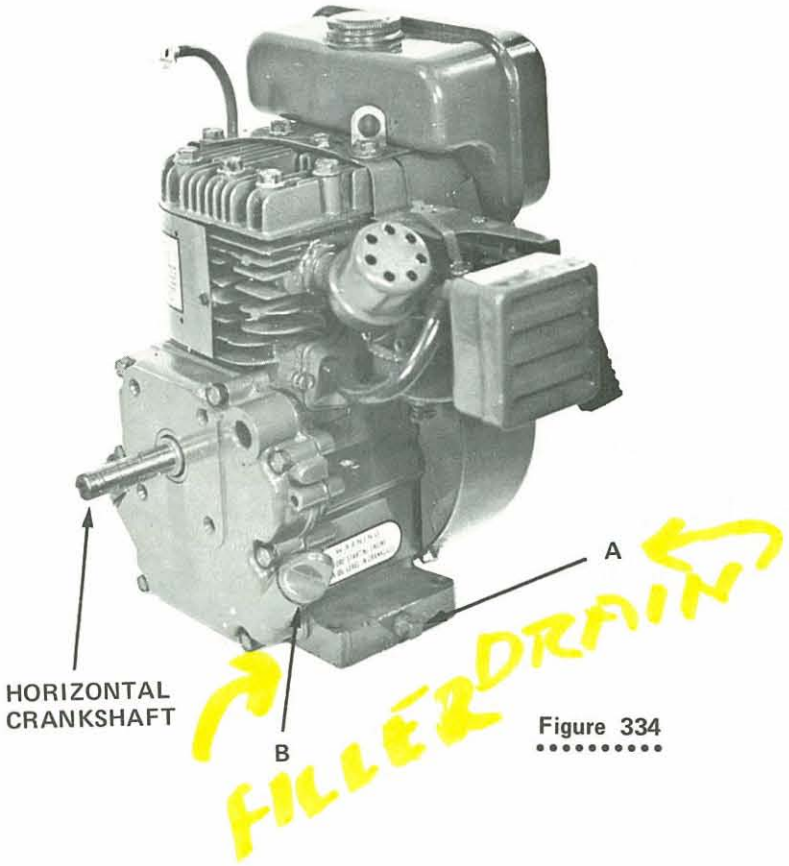


Figure 334

Figure 335

The vertical crankcase engine, shown in Figure 335 has the filler plug located at A. There is a drain plug, shown at B, and on many vertical shaft engines there will be a drain plug on the bottom side just under the filler plug. When using the drain plug at B, it is always good to tilt the engine so all the oil will be drained.

In order to get at the inside of the engine it will generally be necessary to remove the fuel tank, flywheel shroud and the cylinder air baffles. If crankshaft removal is required it will be necessary to remove the flywheel. The spark plug, carburetor and muffler will also have to be removed.

After all restricting equipment has been removed you will be able to get at the cover bearing plate. Figure 336 shows a typical horizontal shaft engine and bearing plate. There are generally six or eight bolts holding this cover plate to the engine housing. The bearing cover plate, shown at A, has a gasket between the plate and the housing. Be careful when removing as the gasket can often be saved if it does not already leak or is damaged when removing.

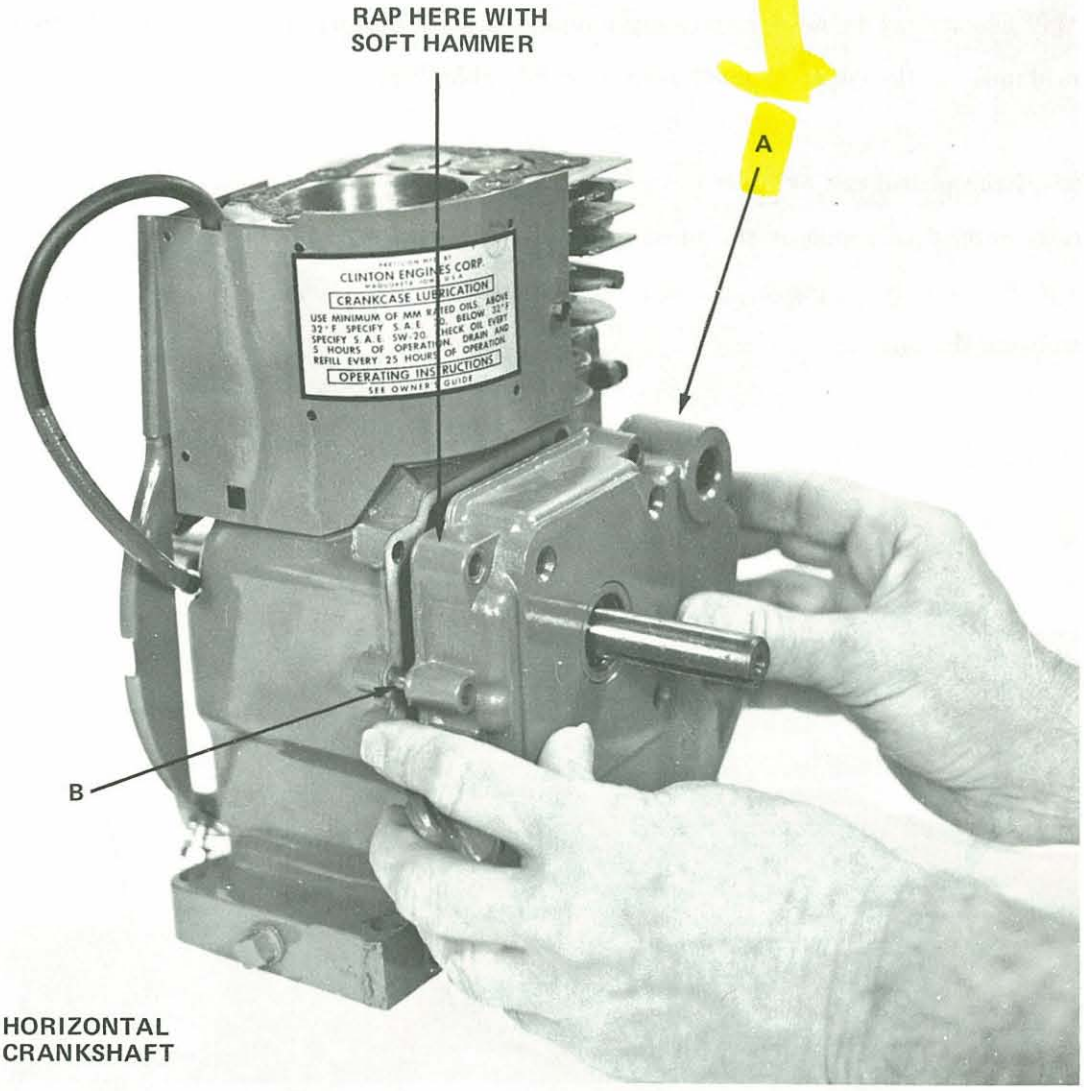


Figure 336

Sometimes the cover plate will not want to come off easily and it may be necessary to rap a few times with a soft hammer or piece of hard wood. This plate is generally located on the housing with two or more dowel pins shown at B. These pins prevent the housing from being installed wrong and locate it so all the bolt holes will line up. Before trying to pull the plate off, be sure the crankshaft is clean.

Figure 337 shows a horizontal shaft 4-cycle engine with the bearing plate removed. The crankshaft bearing is shown at A and the camshaft bearing is at B. These bearing plates will generally have locating dowel pins the same as the vertical shaft engines. After the head and the bearing plate have been removed, inspect the top of the cylinder wall for carbon deposits and evidence of a ridge. If there is a ridge around the top of the cylinder wall, it may be necessary to use a ridge reamer to remove it before the piston can be removed. The presence of a ridge that you can easily feel would indicate both the piston and the cylinder are worn considerably and it may be necessary to make repairs using the short block assembly. Extreme wear at this point would indicate the entire engine has had considerable wear.

Very often if the piston and cylinder show heavy wear the valves will also show the same condition and the short block method of repair is the most profitable way to repair the engine. If just a small amount of carbon is present on the piston head and around the top of the cylinder, you can scrape it off with a knife before removing the piston.

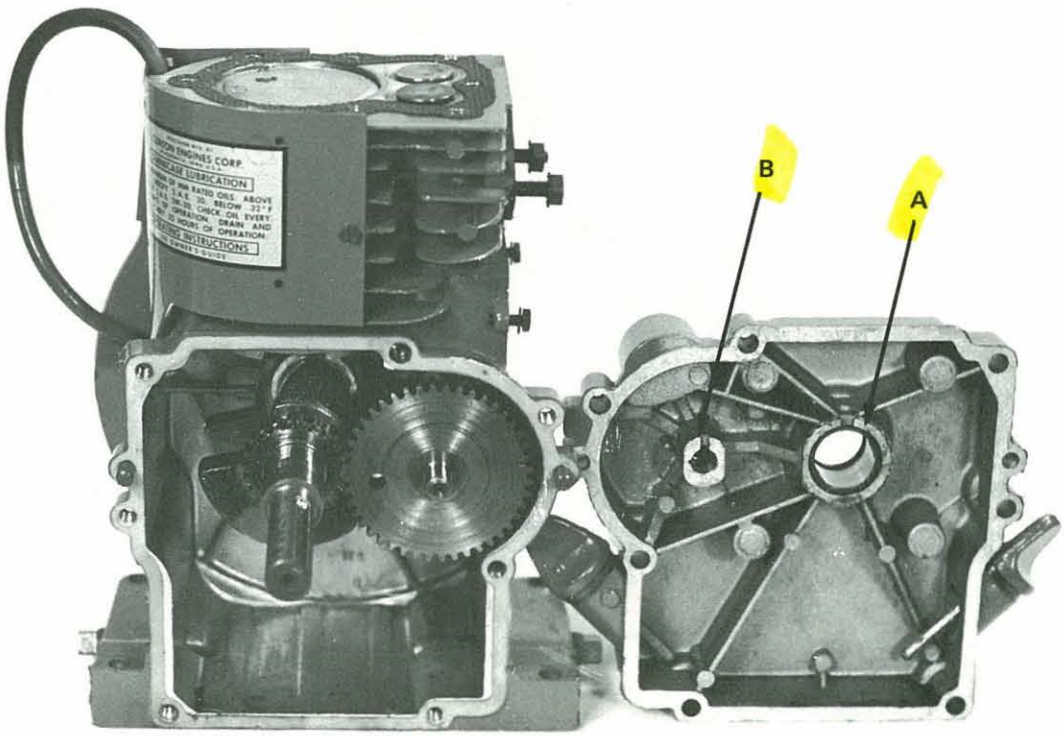


Figure 337

Earlier we covered the basic functions of the piston, rod and ring assembly and how they changed reciprocating motion to rotary motion. First, let's review the piston and rod assembly we studied earlier.

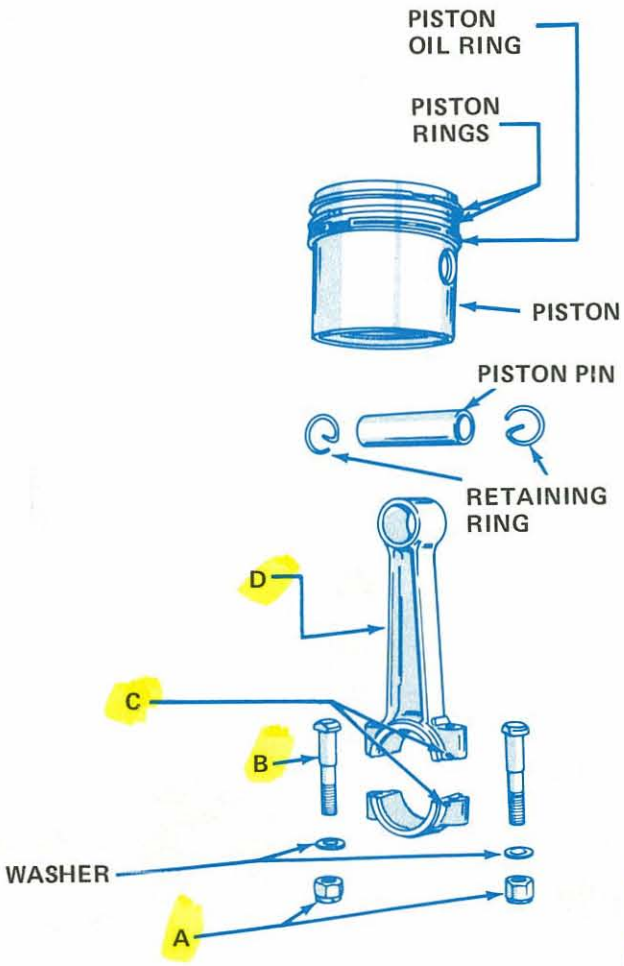


Figure 338

Figure 338 shows the parts that make up the complete piston and rod assembly. The nuts shown at A are the first to remove and then the connecting rod bolts shown at B. The rod cap will then slip off. When removing the rod cap be sure to note the match marks shown at C. It is very important that the rod caps be reinstalled with these marks matching each other. Sometimes the marks will be an indentation in the metal, others may have a small raised part. By studying the rod and cap carefully you will be able to see these matching marks. If you cannot identify any matching marks it would be a good idea to take a small punch or chisel and mark them.

After the rod caps have been removed, the connecting rod D, piston pin and piston can generally be removed by pushing the entire assembly out the top of the cylinder. Some engines may require removal from the bottom of the cylinder. There are some engines made with the cylinder head as part of the cylinder. The head is not removable and does not use a head gasket. The majority of the small engines you will be working with will be designed so the piston assembly can be removed from the top. Some engines will have a self-locking nut holding the rod cap, others may have a locking tab that must be bent out before you can get a wrench on the rod cap nut.

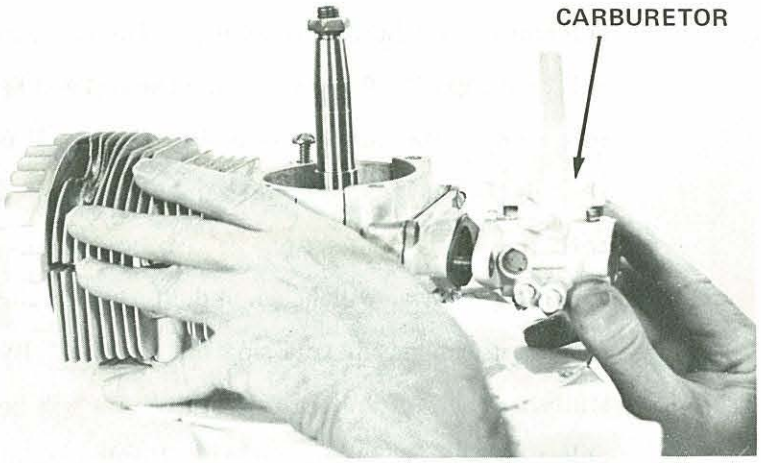


Figure 339

REMOVING 2-CYCLE PISTON AND ROD ASSEMBLIES

The piston and rod assembly is removed from 2-cycle engines very much the same as the 4-cycle engine. First, all restricting parts have to be removed to get at the carburetor and reed valve assembly. Figure 339 shows a typical 2-cycle engine ready for disassembly. After the carburetor linkages are out of the way, remove the carburetor from its two holding bolts. There are generally only two bolts holding the carburetor.

After the carburetor is removed you can get to the reed valve assembly shown Figure 340. We covered the function of the reed valve earlier. The reed valve assembly is generally held with four bolts and will slip straight out after they have been removed. On some engines you can remove both the reed valve and the carburetor together. Most repairmen remove them separately so the carburetor can be cleaned and the reed valves can be inspected.

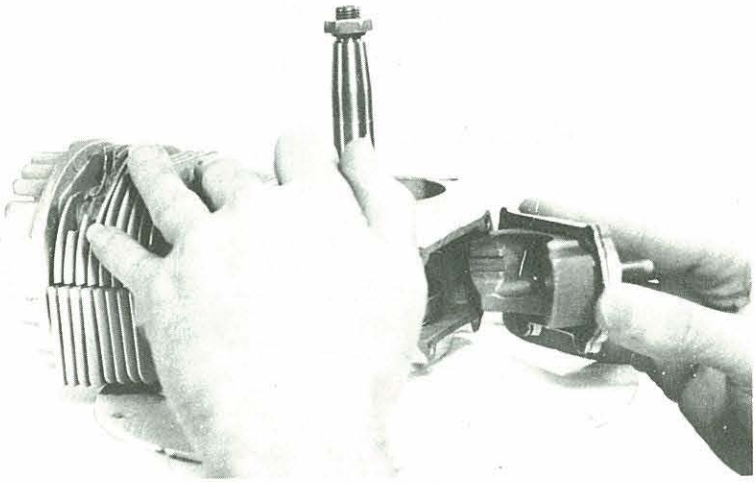


Figure 340

After you have both the carburetor and the reed valve assembly removed you can get at the rod cap bolts as shown in Figure 341. Move the piston to the bottom of the stroke so the rod cap bolts will be easily accessible. The piston and rod assembly can then be removed the same as 4-cycle engines. Pay particular attention to the markings on the rod cap so it can be reinstalled the same way.

There are several reasons for noting the position of the rod cap. Some cannot be changed as they may be offset and will cause a binding action if installed wrong. This is particularly true in some automobiles as both the rod and rod cap may be offset. The wear pattern between the crankshaft and the rod develops in such a way that it is not advisable to change them back and forth even though they may work. One important reason for noting the position before removal is the oil dipper. Some engines have a dipper or scoop that dips into the oil on 4-cycle engines to help distribute the oil in the crankcase. The 2-cycle engines do not have this type oil feature since the fuel and oil are mixed together.

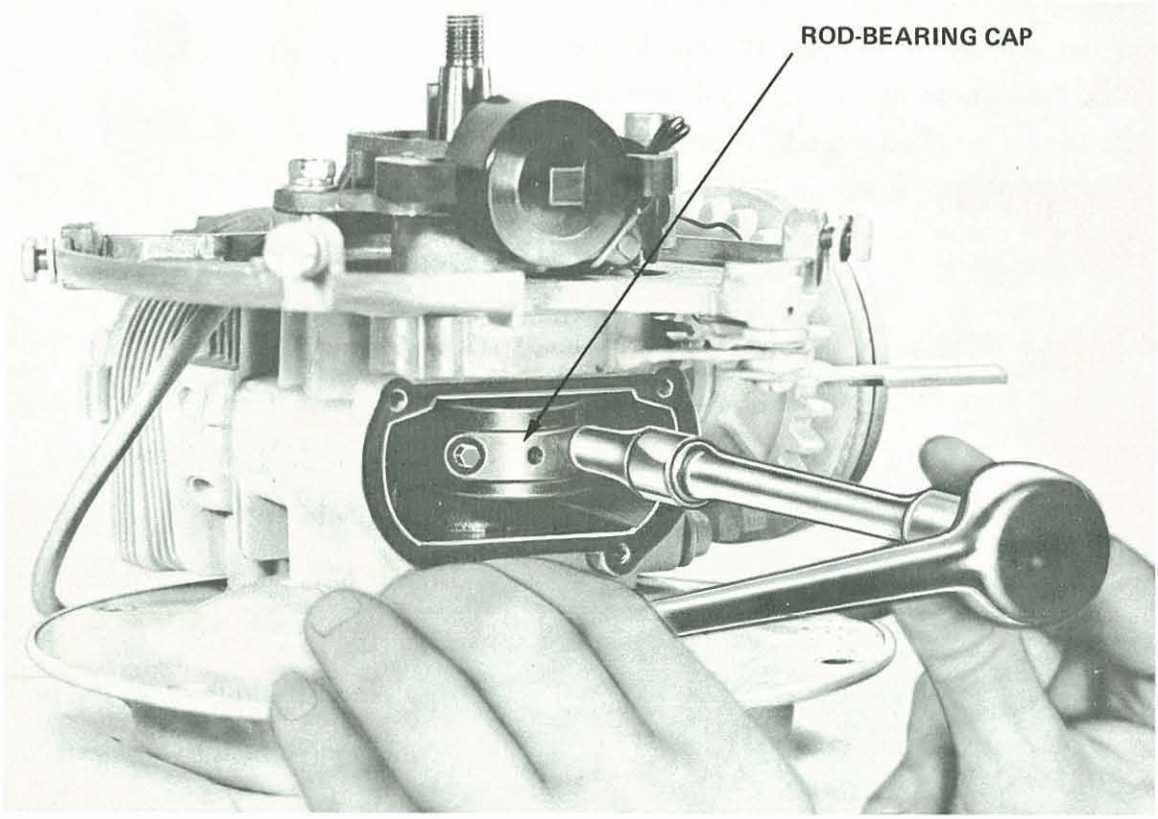


Figure 341

PISTON AND RING INSPECTION

A great deal can be determined about the piston and rings before they are removed from the cylinder. Removal for inspection is the last resort to determine their complete damage. After the piston has been removed it can be cleaned with a special carbon solvent or brushed with a wire brush. The top can be cleaned with a scraper.

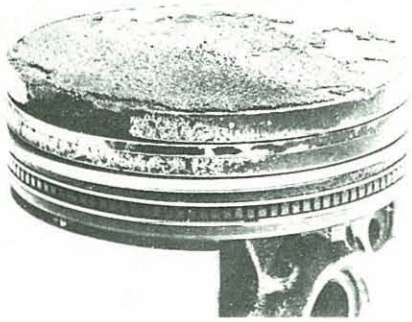
Scoring, as shown in Figure 342, is one defect in a piston that can only be determined after it has been removed. Scoring is the result of metal getting so hot it begins to melt. As a result of lack of lubrication the parts will reach the melting point and begin to fuse, or weld themselves together. This scoring will generally show up both on the piston wall and the inside of the cylinder. When this condition exists, not only the piston must be replaced but the cylinder wall will generally have to be rebored to a larger diameter. This will also require a new over-size piston and rings.

SCORING

Figure 342

Small scratches on the piston or cylinder wall will sometimes not actually be scoring. It could be the result of excessive wear due to dirt and abrasives getting into the engine. This generally comes through the carburetor air cleaner, intake manifold or through the oil system.

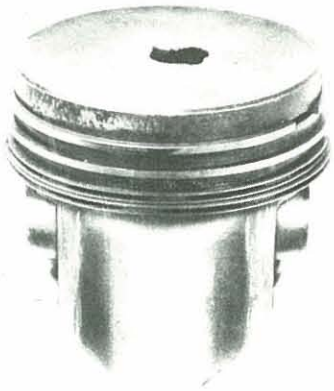
Check for burning at the top of the piston and broken or stuck top ring. This could be caused from detonation as shown in Figure 343. Detonation occurs when fuel burns unevenly. Only part of the fuel is burned when ignited by the spark plug, the unburned portion will be compressed until it reaches the point of self-ignition. This causes a hammering force on the top of the piston, instead of a uniform pushing force. New modern fuels have helped considerably to eliminate this problem. Fuel with an octane rating that is too low will cause this problem.



DETONATION

Figure 343

A piston with a hole in the top, like the one shown in Figure 344, is caused from pre-ignition. The ignition occurs earlier than intended and actually is trying to force the piston back down long before it has reached its firing position. This pre-ignition is working one force against the other and will sometimes knock a hole in the top of the piston. Excessive carbon build-up on top of the piston will sometimes cause this problem. A flake of hot carbon may ignite the fuel mixture before the spark plug ignites.



PRE-IGNITION

Figure 344

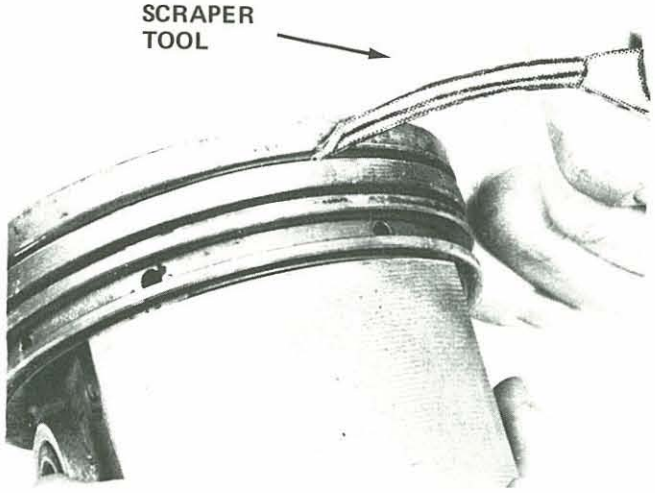
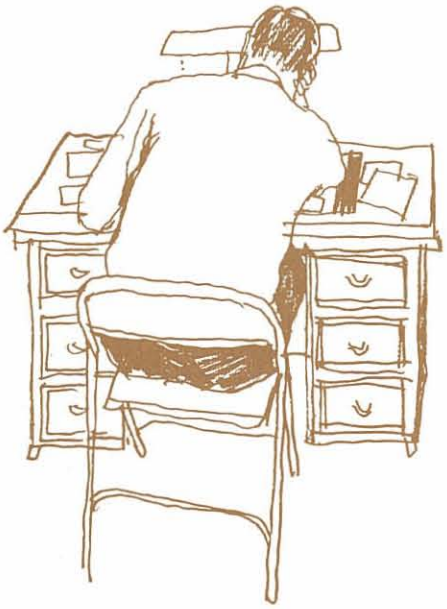


Figure 345

Carbon will often accumulate in the ring groove. There are special tools available for removing carbon from the ring groove, however, a broken ring, as shown in Figure 345, will do a very good job of cleaning carbon out of the ring grooves. Take an old ring and break it in half. Rings are very brittle and will break easily. Be sure to wrap tape around one end as it will be very sharp.

ROD AND BEARING INSPECTION

A very simple check of the rod and bearing can be done before you remove it. Check for any sign of play or movement up and down or sideways. Hold one finger or thumb on the rod cap and crankshaft. Move the piston up and down by turning the crankshaft. Make this check with the piston in several positions. Next, check for side play the same way. If the rod and bearings are in good condition, you should feel practically no movement. Almost any movement that you could detect would indicate new rod bearings were needed.



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1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
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EXAMINATION ON LESSON 34
PISTON AND ROD REMOVAL

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(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Scoring will generally show up on both the piston and the insides of the cylinder. _____
   TRUE
   FALSE

2. There are some engines made with the cylinder head as part of the cylinder. _____
   TRUE
   FALSE

3. Fuel with an octane rating that is too low will cause _____. _____
   a. detonation
   b. uneven burning
   c. both of the above

4. The presence of a ridge at the top of the cylinder would indicate both the piston and the cylinder are worn. _____
   TRUE
   FALSE

5. When a scoring condition exists, the _____ will generally have to be replaced and the cylinder rebored. _____
   a. rod
   b. crankshaft
   c. piston

6. If there is a ridge around the top of the cylinder wall, it will generally be necessary to use a reamer to remove it before the _____ can be removed. _____
   a. piston
   b. cylinder
   c. neither of the above

7. Two cycle engines do not use the dipper or scoop method to distribute the oil in the crankcase area. _____
   TRUE
   FALSE

8. Detonation occurs when fuel burns _____. _____
   a. evenly
   b. unevenly
   c. makes no difference

(Continued on page 2)

9. Very often if the piston and cylinder shows heavy wear the valves will show the same condition. _____
   TRUE
   FALSE

10. The majority of small engines will be designed so the piston assembly can be removed from the _____. _____
    a. bottom
    b. top

11. When removing the rod cap, be sure to note the location of the match marks. _____
    TRUE
    FALSE

12. When only part of the fuel is burned the unburned portion will be compressed until it reaches the point of self-ignition. _____
    TRUE
    FALSE

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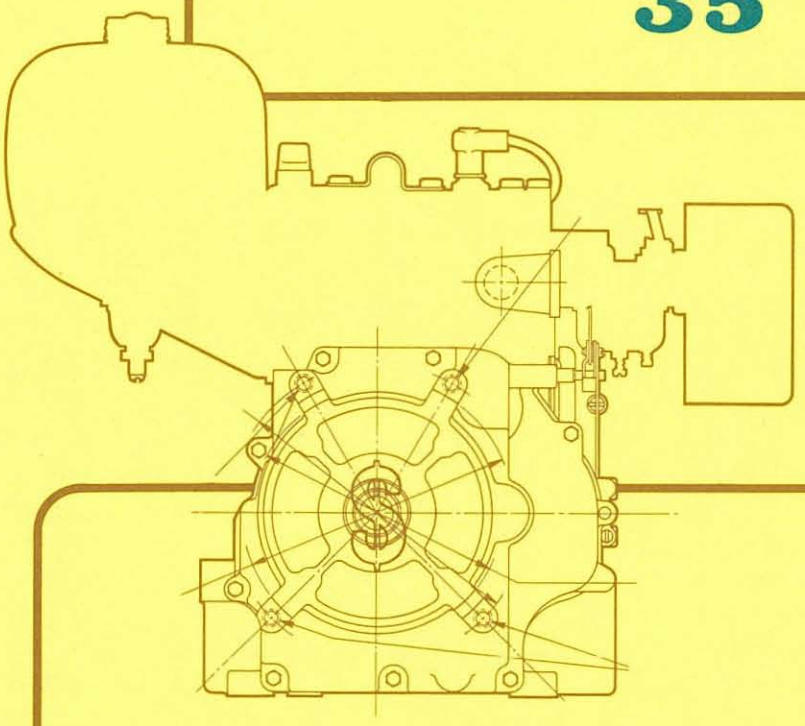
LESSON NUMBER

35



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...and let's find out all about --

INSTALLING ROD BEARINGS, RINGS AND PIN

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ROD AND WRIST PIN BEARINGS

Figure 346 shows a typical rod and bearing assembly. There are two types of bearings used on most small engines. They may be either a plain sleeve bearing or needle bearings. Many engines are now using the needle bearings. The needle bearings, shown at A, are contained in a housing and are made to be pressed into the wrist pin end of the connecting rod.

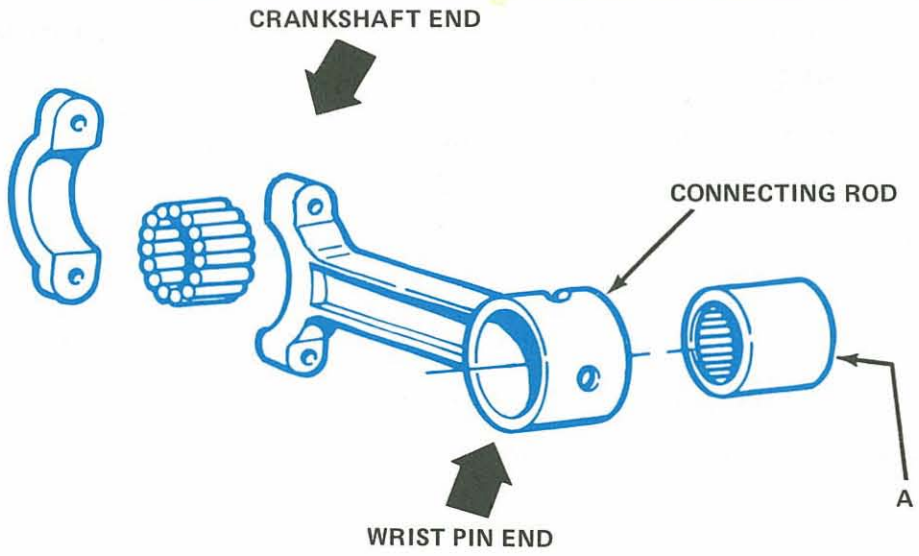


Figure 346

On examination of one of these bearings, you will notice there is lettering or numbers on one end, as shown in Figure 347. Always use a driving tool of the same diameter and drive the bearing from this end to remove it. Reinstall the same way.

The needles on the crankshaft end of the connecting rod are not caged and, therefore, present a little different procedure for installation. These bearings cannot be slipped around the crankshaft. They are individual bearings and must be installed around the outside surface of the crankshaft. When removing the old bearings be sure to pick all the needles off the crankshaft and any that may have fallen into the crankcase.

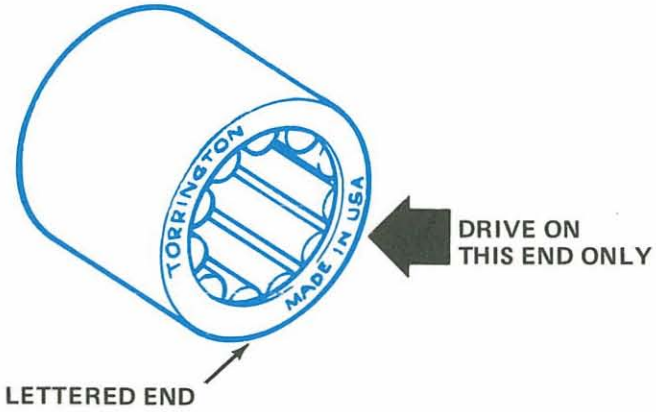


Figure 347

To install new needle bearings, coat the inside surface of the rod and cap with grease. Lay the needles in place in the cap and rod. Be sure the match marks on both the rod cap and the rod are on the same side.

Other types of rod bearings use an insert plain bearing that fits just inside the rod cap and another inside the crankshaft end of the rod. Wear of this type bearing can sometimes be corrected by filing a slight amount off the face of the rod cap. Be sure to take off the same amount from both sides. Very little filing will be needed. Too much filing will result in the rod and rod cap freezing to the crankshaft. When at all possible, filing of the rod cap is not recommended.

PISTON AND ROD DISASSEMBLY

Before disassemblying the piston and rod for repair, inspect the condition of the cylinder. We'll cover cylinder inspection in more detail later. If the cylinder is in bad condition it may be necessary to rebore it. This will require an oversize piston. It may require a short block, which is the most practical method of this major repair.

Some rods are offset in the cylinder. The rod does not fit directly in the center of the cylinder. It may be offset to the right or left and must be reinstalled this same way in order to line up with the crankshaft. Pay particular attention to the rod assembly before beginning to remove it. If you are not sure, mark both the piston and the rod so you will be sure to reinstall them the same way.

The piston pin is held in place with two retainer rings as shown in Figure 348. There is one retainer on each end of the pin. It may be a "G" type retainer as shown. This type retainer can be removed with long-nose pliers.

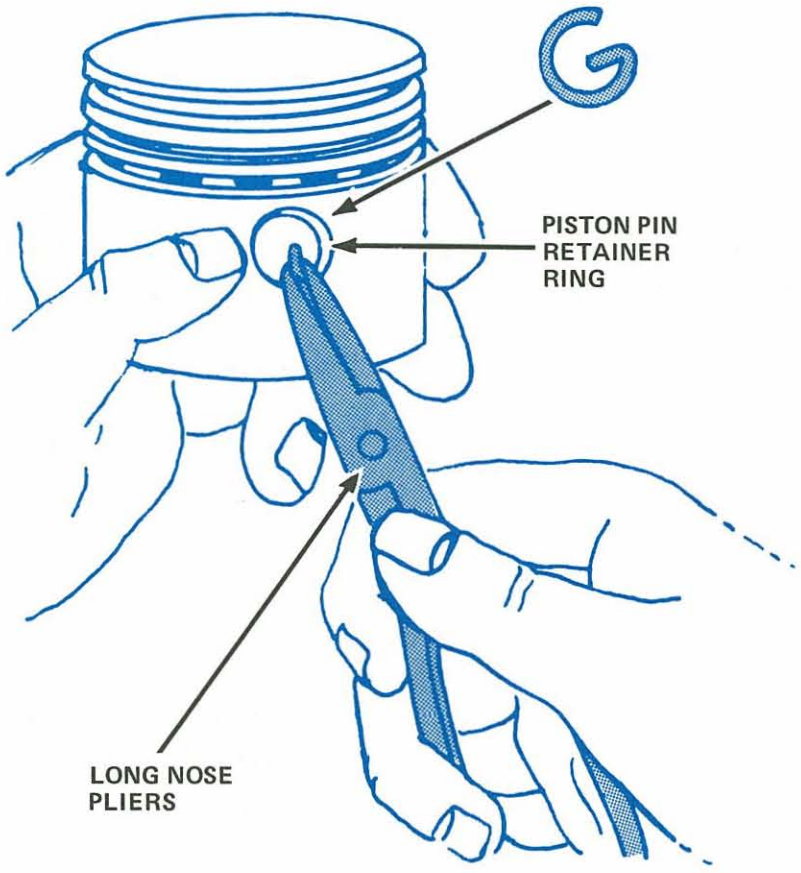


Figure 348

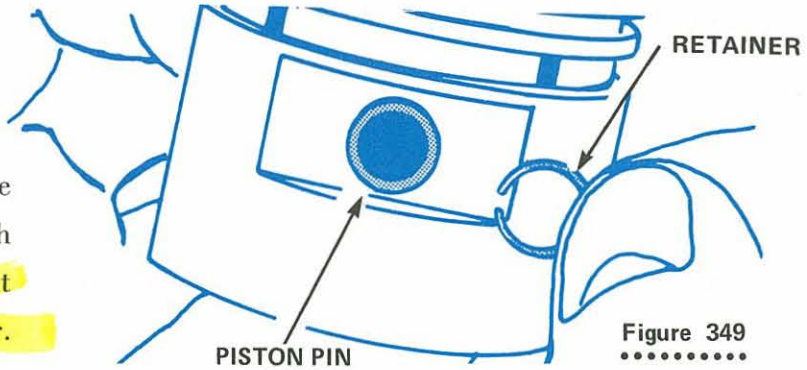


Figure 349

Another type of retainer is shown in Figure 349. It has no provisions for removal with pliers. This type retainer must be pried out with a small sharp tool or small screwdriver.

Some engines may have needle bearings or plain bearings in the piston. After the retainers have been removed, the pin can be driven out of the piston as shown in Figure 350. Use a brass or other soft metal punch and drive the pin out of the piston.

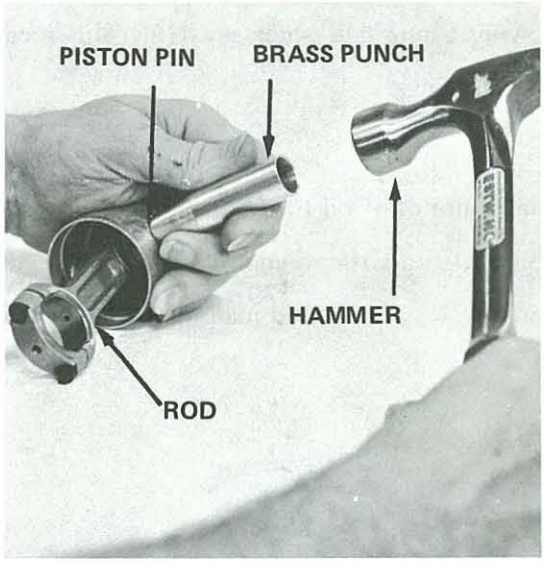


Figure 350

Before removing the rings, examine them carefully. Compare them with the new rings you are going to install. Rings are different and must be installed correctly. Figure 351 shows several different kinds of rings. Remove one ring at a time and, until you are more experienced, it would be a good idea to mark the ring and its location so the same style new ring can be installed. The old rings can be bent apart and they will break.

Figure 351

There is a special tool available for removing rings without breaking them, however, there is no particular advantage to this, since there should be no reason for reinstalling old rings. There is also a tool for installing new rings.

INSTALLING RINGS AND PIN

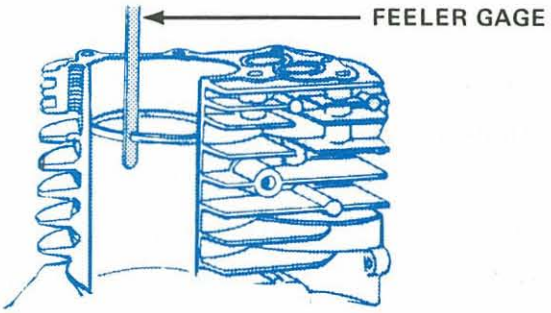


Figure 352

Before installing the rings on the piston you should check the end gap of the ring when it is fitted inside the cylinder. First, slip the ring inside the cylinder, then insert the piston upside down to get the ring square in the cylinder. Push the ring down only about 1-inch. The piston will align the ring square in the cylinder, in the same position it will operate. With a feeler gauge, as shown in Figure 352, check the end gap of the new ring. The space between the ends of the ring should be from .025-inch to .045-inch. If the end gap is too small, file or grind off the end of the ring square to the proper gap. If the ring gap is too large, it is very possible you have an oversize piston and a rebored cylinder. If the piston is oversize, it should be stamped on top showing a number, such as .015. This means that the piston is fifteen thousandths oversize and requires oversize rings.

Apply a small amount of oil to the piston and rings and install the rings as shown in Figure 353. Begin with the bottom ring. Start the open end of the ring in the slot first, then push it over the top of the piston and into position. Be very careful in making this installation as it is very easy to break the ring. Be sure the ring is right-side-up before you begin installing it and be sure you are installing the right ring in the right slot.

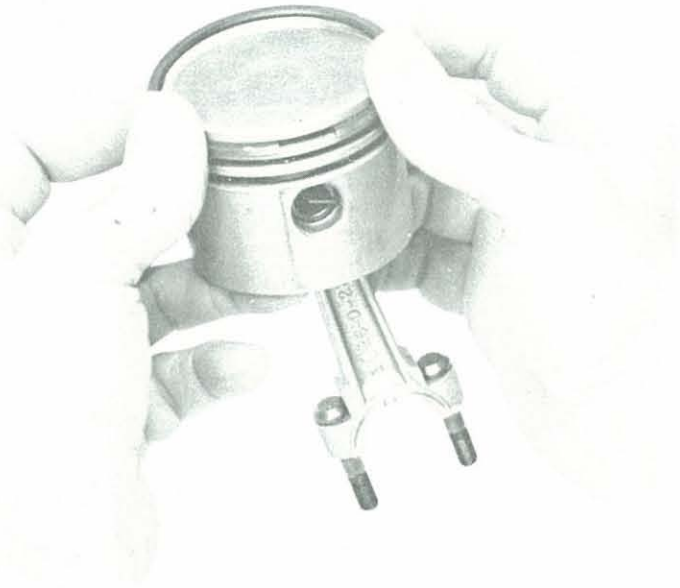


Figure 353

After each ring is installed, check it for freedom of movement in the groove. If they are not free to move in the groove there is danger of scoring the cylinder wall and breaking the ring after very little operation.

The ring gaps should be staggered and not in line with each other. It is a good idea to stagger each alternate ring gap 180 degrees apart. Ring expanders, as shown in Figure 354, are sometimes used under the oil ring. If the engine you are working on uses ring expanders, install them just before you install the ring. They are sometimes used with oil control rings to help maintain its tension as the ring wears. It also helps the oil ring take the shape of a slightly distorted cylinder wall. You will find ring expanders only on 4-cycle engines since 2-cycle engines do not have oil control rings.

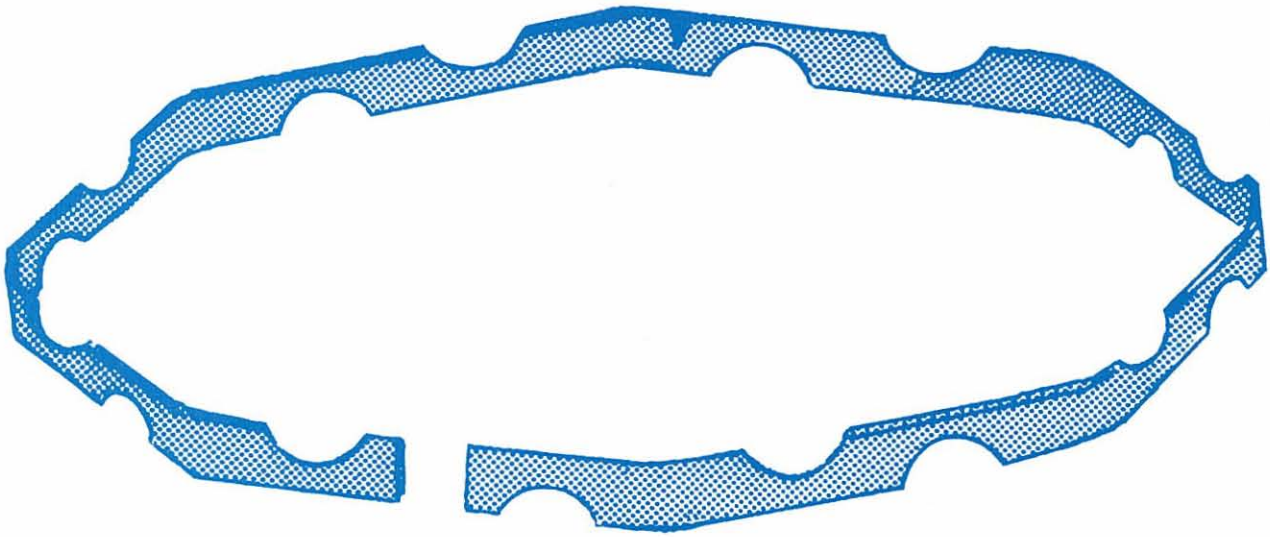


Figure 354

Sometimes ring expanders are used on the two lower rings to compensate for an out-of-round cylinder. It is not necessary to remove the rod from the piston when installing new rings. If the rod is removed from the piston, you can reassemble it in reverse order. Install one of the pin retainers, then the pin and the other retainer. Because of some offset rods, be sure to reinstall the rod so it faces the same side of the piston.

INSTALLING PISTON AND ROD

Before beginning to install the piston, rod and ring assembly, oil the inside of the cylinder wall and the rings. Oil will make the rings easier to install and supplies some lubricant when the engine is first started before normal lubrication begins.

It's best to use a ring compressor when making this installation, however, each ring can be worked into the cylinder individually by hand if a compressor is not available.

When using a ring compressor, install it around the piston and rings as shown in Figure 355. Compress the rings completely by turning the control wrench and then release just a little so the piston can slide inside. The top of the ring should be flush with the bottom of the ring compressor as shown at A. Install the rod end in the cylinder, making sure it is being reinstalled so the rod marks are on the same side of the cylinder as they were removed.

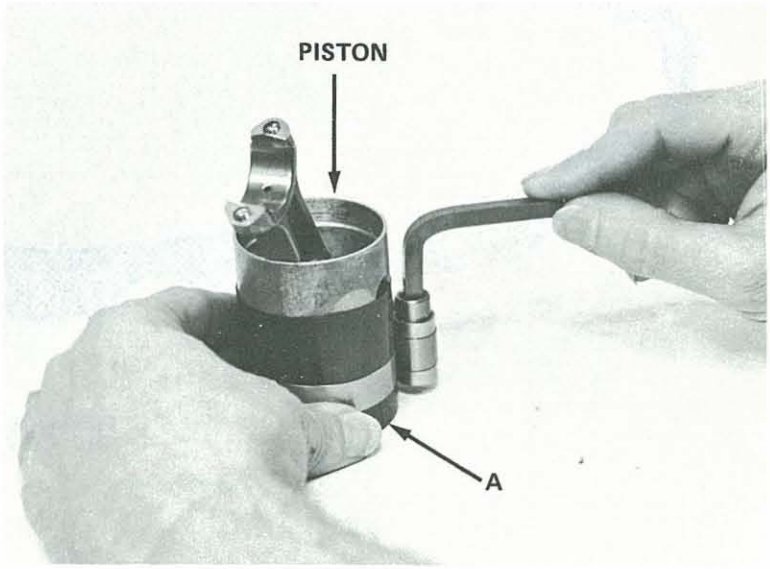


Figure 355

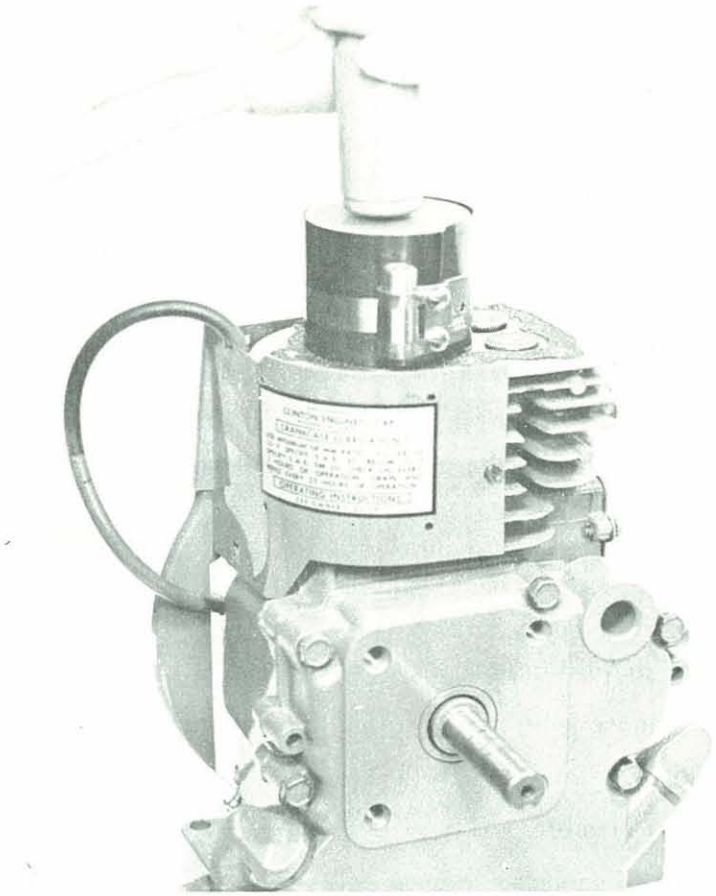


Figure 356

Center the ring compressor over the cylinder, as shown in Figure 356, and tap the piston into the cylinder. The piston should go in easily with no binding. If the piston stops and does not want to go further, do not force. If the ring compressor is not installed properly, one or more of the rings may hang up on the top of the cylinder wall. Forcing will break the ring. Readjust the ring compressor and try again if one of the rings binds on the top of the cylinder.

Install the rod bearing cap and oil dipper if it is attached to or goes with the rod cap. Be sure the match marks line up with the rod and cap. Install the rod cap bolts and tighten to specified torque given in the torque tables.

CYLINDER INSPECTION

There are three types of cylinders used on small engines. The cast iron cylinder is part of the cylinder block. There is also an aluminum cylinder that is part of the aluminum cylinder block. Another type uses an aluminum cylinder block with a steel sleeve inside.

Cylinders are subjected to extreme heat but the heat is not uniform. Figure 357 shows the difference in temperature produced by engine combustion and friction of the piston and cylinder. The top of the cylinder near the combustion chamber, shown at A, may have temperatures of 1300 degrees or more. The bottom of the cylinder is partly cooled by the crankcase and temperatures may be as low as 300 degrees. The cylinder walls on all air-cooled engines conduct heat from this area to the cooling fins. If the cooling fins are not kept clean, excess heat will be developed.

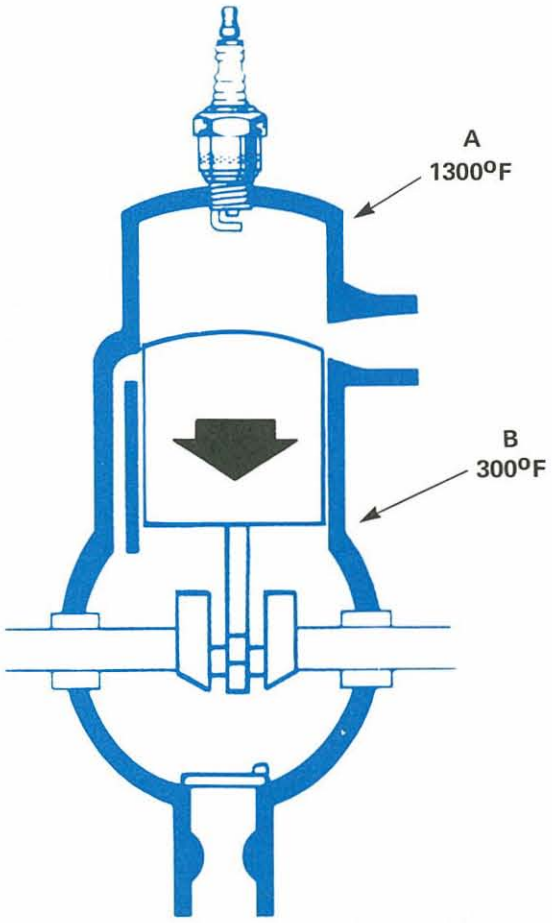


Figure 357

All metal has a tendency to deteriorate more as heat increases. This is why cylinders wear more at the top. Not only is the greatest heat generated in this area, but the piston and the cylinder receive the greatest amount of stress because of the force exerted on it by the combustion.

As the cylinder wears, it leaves a ridge around the top, which will have to be removed before you can take the piston out. Trying to remove a piston from a cylinder with a ridge will generally result in a broken ring and possible cylinder damage.

If you have measuring tools, you can check the allowable tolerances for a taper or out-of-round cylinder, as shown in Figure 358. An inside micrometer can be used to check cylinder wear. Measure the inside diameter of the cylinder as shown at A. Turn the micrometer 90 degrees and take another measurement in the same area. Record this measurement. Take two more measurements at 90 degrees from each other at the top of the cylinder at B. Take these measurements below the ridge mark if one is present on the cylinder. Take the same measurements at the bottom of the cylinder in the area shown at C. After you have taken these measurements, find the difference between them.

The maximum allowable taper in most small engines should be between .004-inch and .008-inch. This means the difference between the largest and smallest measurement between top, center and bottom of the cylinder should not exceed .008-inch. The out-of-round should not exceed .003-inch.

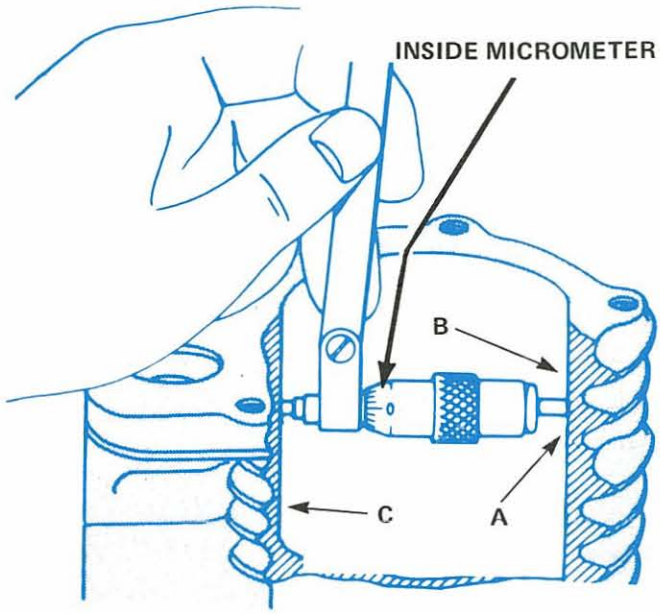


Figure 358

The easiest way to record these measurements is to enter them on a chart, as shown in Figure 359. This chart shows an example of what you might get when checking a cylinder that is in fair condition. The top of the cylinder measures 2.6260-inches and when rotated 90 degrees the measurement was 2.6270-inches. This is .0010-inch difference, making it that much out of round at the top. The center and bottom show the same out-of-round measurements. The maximum safe out-of-round measurement is .003-inch. At this point you could consider this cylinder to be in fairly good condition.

CYLINDER WEAR CHART

	1st Reading	Rotate 90°	Out of Round
*Top	2.6260	2.6270	.0010
Center	2.6250	2.6240	.0010
**Bottom	2.6245	2.6235	.0010
*Maximum	2.6260	2.6270	
**Minimum	2.6245	2.6235	
Taper	.0015	.0035	

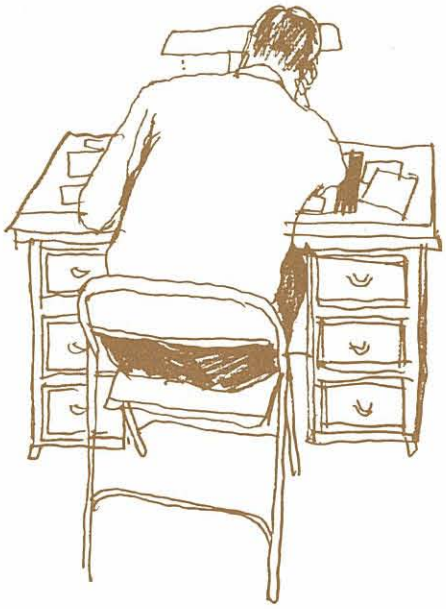
Max. Taper .008"
Max. Round .003"

Figure 359

Now, let's look at the taper measurements. On the first reading the maximum reading of 2.6260-inches is at the top of the cylinder. The minimum reading of 2.6245 is at the bottom of the cylinder. This shows the cylinder is worn .0015-inch more at the top, which gives it this much taper. The second reading shows a taper of .0035-inch. The maximum safe taper should be .008-inch. This is well below the safe range so the cylinder could be considered in good enough shape for rings without reboring.

In addition to checking for out-of-round and taper of the cylinder, you should also look for any signs of scoring, cracks, stripped bolt threads or broken fins.

If a cylinder shows much over the safe tolerances or has other visible damage, it will very possibly have to be rebored and fitted with oversize pistons and rings. This gets into a rather expensive operation due to the labor time involved and cost of individual replacement parts. Most shops feel the short block method of repair saves them time, costs less for the customer and makes them more profit.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 35
INSTALLING ROD BEARINGS, RINGS AND PIN

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. It is not necessary to remove the rod from the piston when installing new rings. ____
   TRUE
   FALSE

2. The maximum allowable wear taper for most small engines is between _____ and _____. ____
   a. .002 - .004
   b. .004 - .006
   c. .004 - .008

3. Regular standard size rings can be used with an oversized piston. ____
   TRUE
   FALSE

4. Cylinders are generally made of _____. ____
   a. cast iron
   b. aluminum
   c. either of the above

5. The two types of rod bearings used on most small engines are plain sleeve or needle bearing. ____
   TRUE
   FALSE

6. The cylinder walls on air cooled engines conduct heat to the _____. ____
   a. cylinder head
   b. cooling fins
   c. flywheel

7. Rods that are offset in the cylinder may be installed either way. ____
   TRUE
   FALSE

8. When installing new rings the top rings should be installed last. ____
   TRUE
   FALSE

9. The ring endgap on most small engines should be from _____ to _____. ____
   a. .010 - .015
   b. .025 - .045
   c. .035 - .065

10. The highest heat temperature occurs at the _____ of the cylinder. ____
    a. bottom
    b. middle
    c. top

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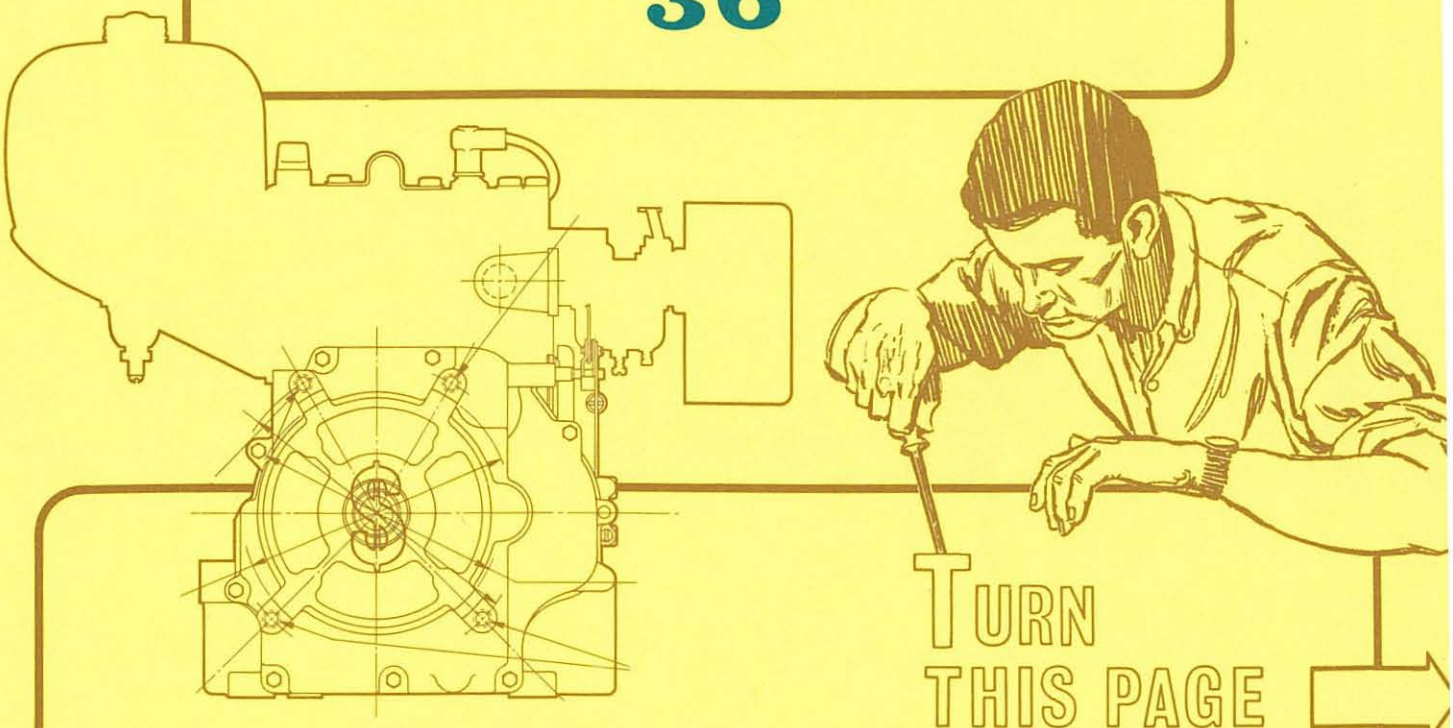
LESSON NUMBER

36



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MAJOR OVERHAUL AND SHORT BLOCK

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CYLINDER REBORING

There are two methods that can be used for reboring cylinders. One is a boring bar that uses a cutting tool. The boring bar is generally not used very much in reboring small engines, however, it is necessary when reboring engines that do not have a removeable head. Most repair shops recommend against attempting to rebore this type cylinder and will use a short block.

The hone method of reboring is preferred by most mechanics for reboring small engines. A hone consists of a tool holding carborundum stones as shown in Figure 360. These hones, shown at A, are just grinding stones that are adjustable and replaceable. They are made of different material for aluminum and cast iron cylinders. The hones are also made of coarse grit material for rough grinding and fine grit for final finish grinding.

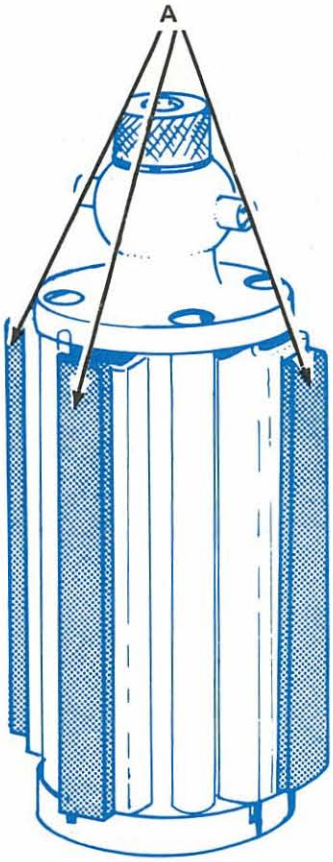

Figure 360

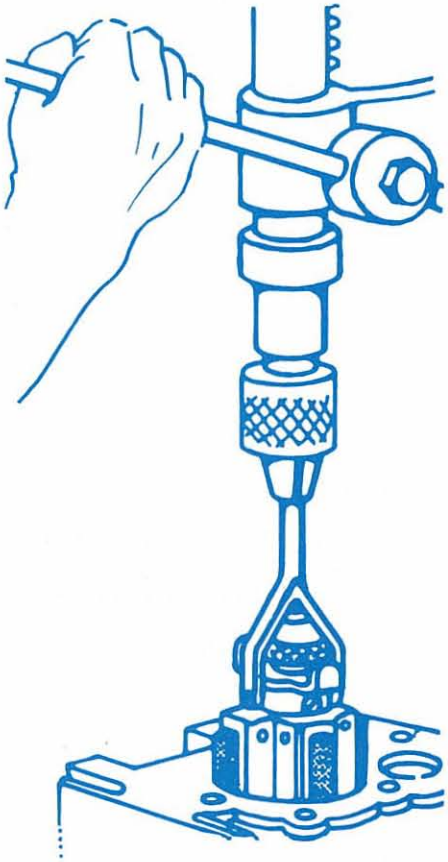

Figure 361

First the hone is chucked in a drill press as shown in Figure 361. The drill press should be set to run from 500 to 650 r.p.m. Adjust the cylinder block directly under the spindle of the drill press and lock it in place with a clamp. Before starting the drill press, lower the hone into the cylinder all the way to the bottom. Adjust the hone so the stones just come in contact with the cylinder. The lower part of the cylinder is smaller in diameter than the top. Turn the hone by hand to be sure it is contacting the cylinder and not binding too tight. Start the drill and move the hone up and down in the cylinder. Keep adjusting the hone until you are grinding uniformly, but very lightly, all the way up and down the cylinder wall.

Make periodic checks with your micrometer and when the cylinder is .002-inch of the desired bore, change to the fine stone and clean up the inside. Clean the cylinder thoroughly with a dry clean cloth and coat the inside with oil.

4-CYCLE CAMSHAFT ASSEMBLY

Earlier we covered some of the principles of the camshaft assembly in its relationship to the valves of a 4-cycle engine. We'll review just a few of these functions along with removal and inspection. The operating principles covered in these next four drawings are very important to thoroughly understand 4-cycle engines.

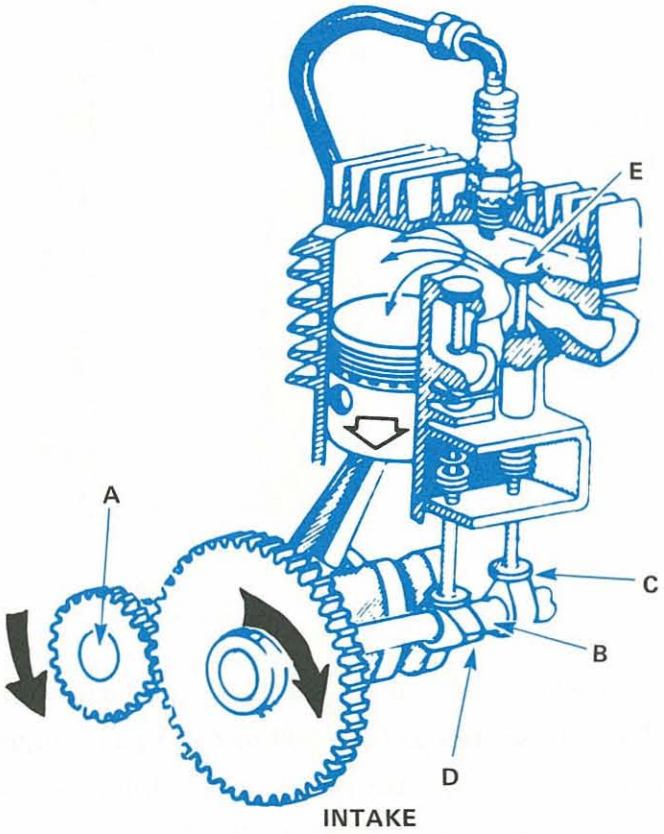

Figure 362

The camshaft assembly opens and closes the valves of a 4-cycle engine at exactly the right time. This action is directly related to the position of the piston at the time the valve is open or closed.

Sometimes the camshaft assembly is related to other functions of the engine, such as the oil pump, governor, compression release mechanism for easier starting and an additional power take-off drive. These are features that may be added to the mechanism of the camshaft assembly and do not change its basic operating function.

Figure 362 shows the crankshaft at A. The crankshaft is connected directly to the rod and piston and turns as the piston goes up and down. The teeth of the crankshaft gear engage directly with the gear connected to the camshaft shown at B. The lobes on the camshaft, shown at C and D, are designed to open and close the valves. As the piston is going down on the intake stroke, valve E is open, because the valve lifter is riding on the high part of the cam C.

The exhaust valve is closed because the valve lifter is riding on the low point of cam D. Fuel is being drawn into the cylinder because the piston is creating a suction by its downward motion and the intake valve is open, allowing fuel to enter the combustion chamber.

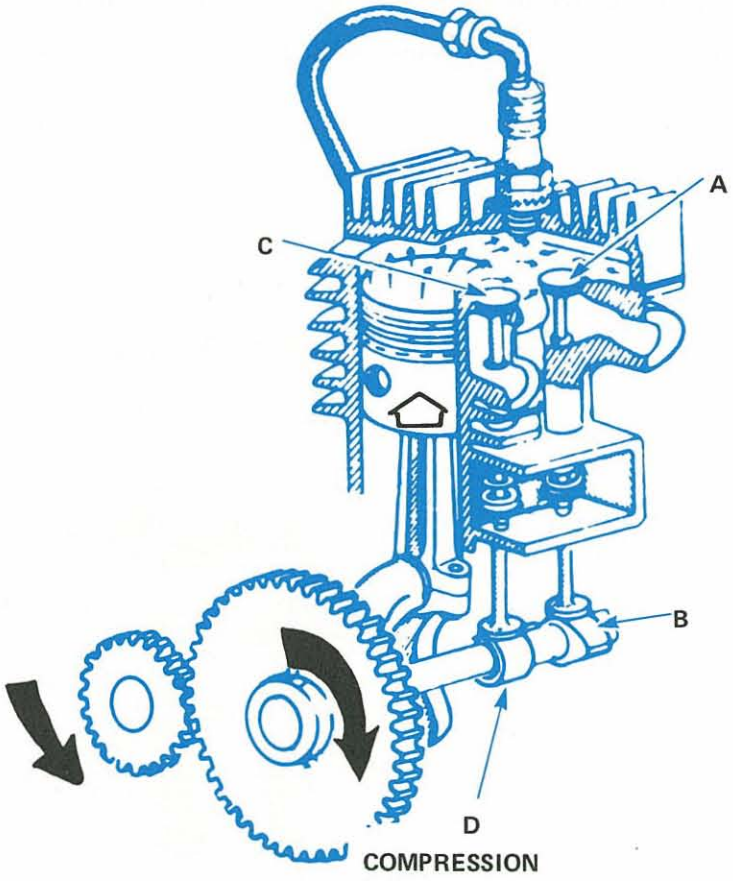

Figure 363

Figure 363 shows the piston on the second, or compression stroke. The intake valve A is closed because it is riding on the low point of the cam shown at B. The exhaust valve C is also closed because it is riding on the low point of the cam D. Since both valves are closed and the piston is going up, the fuel-air mixture is being compressed since it cannot escape with both valves closed.

Figure 364 shows the piston on the power stroke. Both the intake valve at A and the exhaust valve at B are closed. Ignition has just occurred by the spark plug igniting the compressed fuel-air mixture. The piston is being forced down. Both valve lifters are riding on the low part of the cams shown at C.

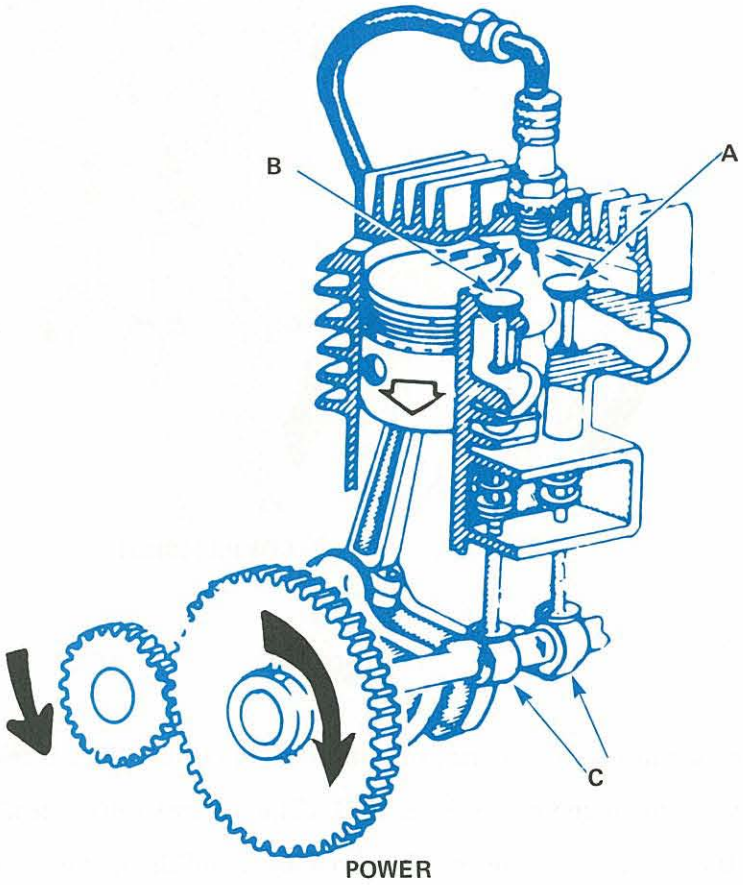

Figure 364

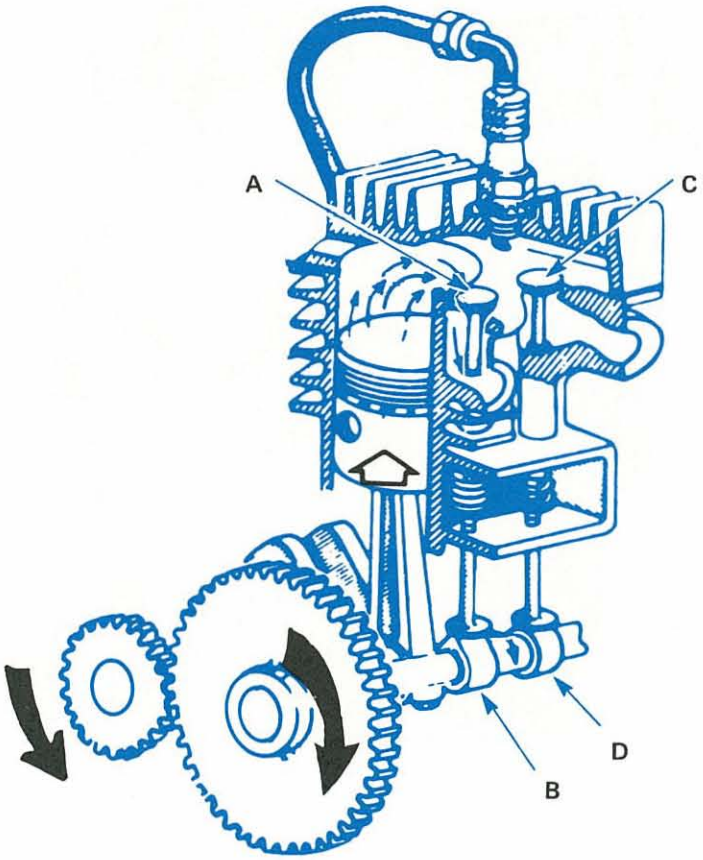

Figure 365

The exhaust stroke is shown in Figure 365. The piston is on the way back up. The exhaust valve A is open allowing the piston to force the burned gases out. The exhaust valve is open because the lifter is riding on the high part of the cam, shown at B. The intake valve, shown at C, is closed because the lifter, shown at D, is riding on the low part of the cam.

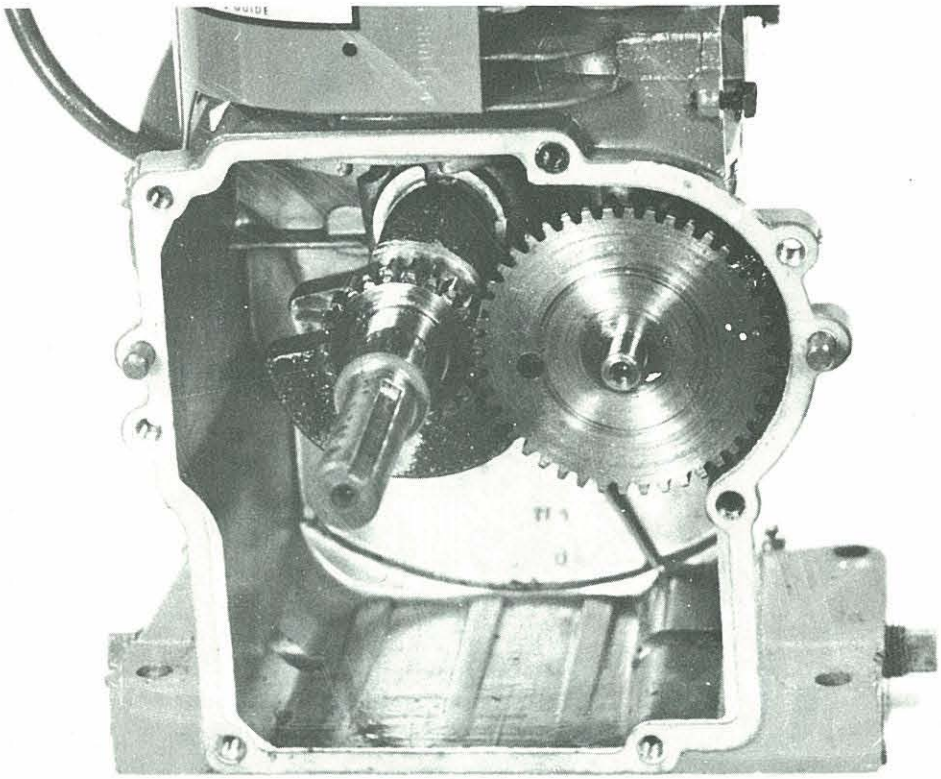

Figure 366

To remove the camshaft for inspection it is first necessary to remove the base plate or gear cover using the same basic procedures as for piston and rod removal. After you have access to the gear housing, as shown in Figure 366, you can begin removal of the camshaft. Before attempting to remove, study these gears carefully to locate the timing marks. Don't assume the gears are marked as some engines may not have markings.

Timing marks may not always have the same appearance. Some may indicate the timing marks as a chamfered tooth, as shown at A in Figure 367. Another method is a chisel or punch mark shown at B. Both gears may be marked with a chisel or punch mark. Some engines may not indicate the timing mark on the camshaft gear and it would be indicated by the small hobbing hole shown at C. The center of this hole will often line up directly with the timing mark and can be used as a timing mark. If there are no indications of timing marks, make them with a sharp chisel or punch before removing.

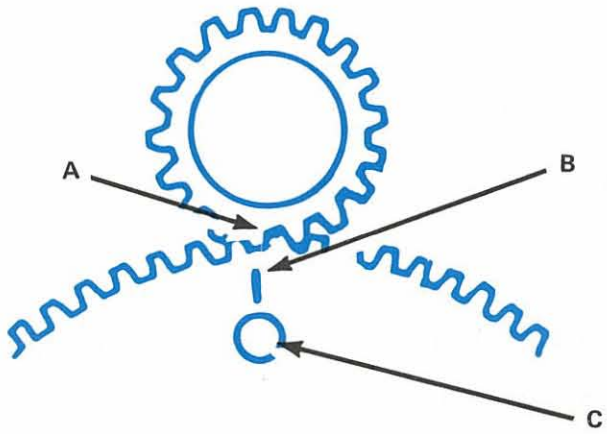

Figure 367

Before removal of the camshaft, it will be necessary to relieve the valve spring pressure. The springs are exerting pressure against the camshaft and will make it difficult to remove unless this pressure is released. Turn the piston to the compression stroke with the valve timing marks lined and both valve lifters will relieve the pressure on the camshaft. They will both be riding on the low part of the cams as shown in Figure 363. This will allow you to pull the camshaft gear straight out without any binding action.

If possible, turn the crankcase on the side or upside down to keep the lifters from falling out. The lifters should always be installed exactly as they were removed, as they are not always the same. After the camshaft is removed, inspect both sides of the gear teeth for cracks or chips and any wear on the cam lobes. Check for any bearing side play on both ends of the shaft.

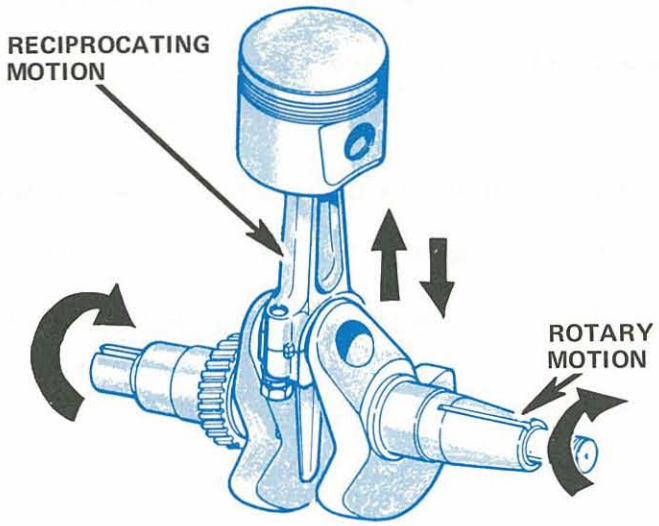

Figure 368

CRANKSHAFT ASSEMBLIES

The basic function of the crankshaft is to convert the reciprocating motion of the piston into rotary motion, as shown in Figure 368. Other functions include a method of providing power for driving equipment. Most small engines used today use the crankshaft as the primary source of power transmission to drive the equipment. Some larger engines may add an auxiliary shaft called a power take-off. This is often referred to as the PTO shaft.

As we covered earlier, the crankshaft drives the camshaft on 4-cycle engines. It turns the flywheel providing the electrical energy needed for both 2 and 4-cycle engines and it provides balance and stability to the engine, by helping to offset the forces exerted by the up and down motion of the piston and rod assembly.

The crankshaft is considered the backbone of the engine. It is the largest single part and subjected to the most force. Each time the piston fires it exerts a bending strain on the crankshaft. The centrifugal force of this heavy piece of metal rotating at high speed causes a great strain on the crankshaft.

CHECKING CRANKSHAFT CONDITION

Crankshafts, even though they are subjected to much rough treatment seldom cause trouble, unless they have been abused by lack of lubrication, bad bearings or damaged through some accident with the equipment they operate.

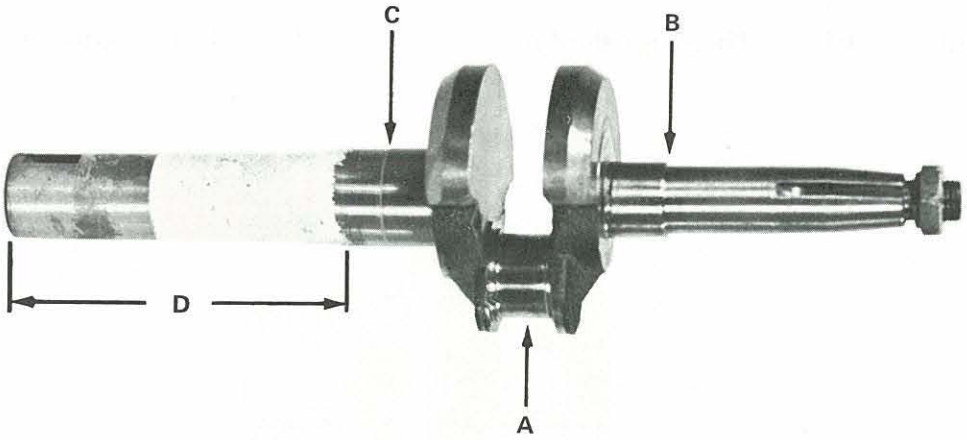

Figure 369

Figure 369 shows the most common wear or damage areas of most crankshafts. The rod connection area, shown at A, can be damaged from bad rod bearings or lack of lubrication. Generally the rod bearing will be damaged first but, if allowed to continue operating, the crankshaft will usually be damaged beyond repair. Two other wear areas are shown at B and C. These are the bearing areas. Bad or improperly lubricated bearings can cause damage in this area of the shaft if allowed to operate for an extended length of time.

The area shown at D is probably the most critical on many small engines. This is the area that is often bent or sprung, particularly on lawnmower applications with the blade attached directly to the crankshaft.

Crankshaft problems are generally apparent while the engine is in operation. Excessive vibration may indicate a bent crankshaft. If the engine is used with a lawnmower blade attached to the crankshaft, the blade should be removed and checked for balance. Very often lawnmower blades are out of balance due to improper sharpening and build-up of foreign matter. Every time a lawnmower blade is sharpened it should be balanced. Noisy operation would indicate worn bearings. Worn rod bearings will be especially noisy.

If the crankshaft is suspected of being bent, sprung or having excessive end play, it can be checked before removing from the engine. One method of checking, though not very accurate, is shown in Figure 370. First, remove the spark plug and turn the shaft by hand to see if you can notice any visual wobble of the crankshaft. The gauge shown at A is attached to some stationary part of the engine and locked in place so the rod is almost touching the crankshaft. Using feeler gauges, check the distance between the gauge and the crankshaft, as the shaft is being rotated. Keep turning the shaft 45 degrees and check the space with a feeler gauge.

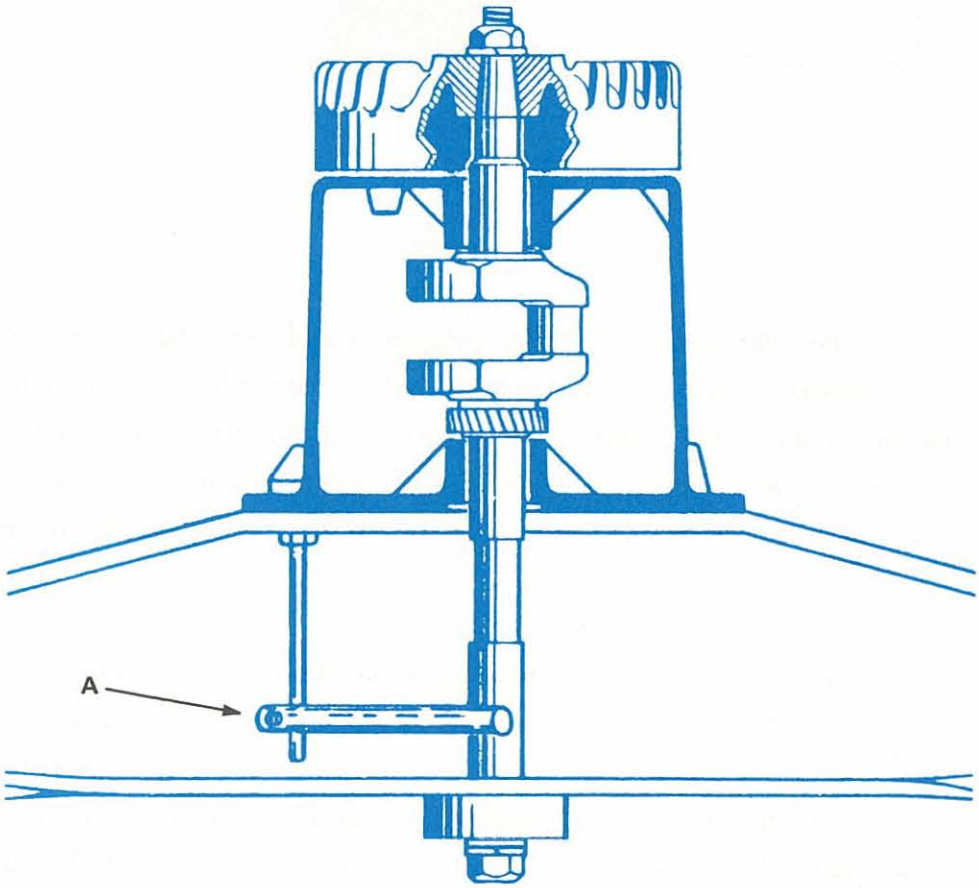

Figure 370

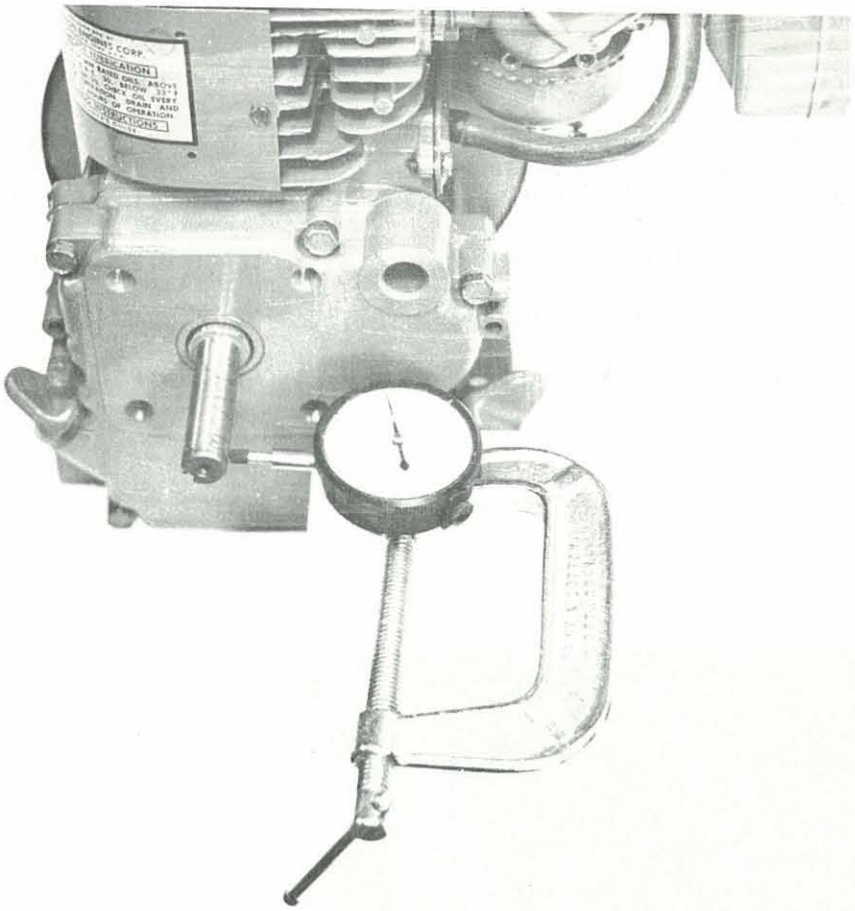

Figure 371

A more accurate method is the use of a dial indicator, as shown in Figure 371. With the dial indicator set as shown, turn the crankshaft slowly and record the minimum and maximum readings of the indicator.

The difference between will give you the amount of deflection in the shaft. Most small engines hold a straightness of .001 to .003-inch. If more than this, the crankshaft should be replaced.

In addition to checking for bent crankshafts, note the amount of end play in the shaft. See Figure 372. Most end play tolerances for small engines have a factory allowable tolerance of .008 to .018-inch. If the end tolerance exceeds .025-inch it should be corrected. You can sometimes correct end play problems by adding or removing gaskets or shims under the bearing plate.

Any worn or damaged crankshaft should always be repaired or replaced. Often it is much better to correct any crankshaft repairs with an entire short block. Generally wear or damage in this area would indicate problems in other parts of the engine.

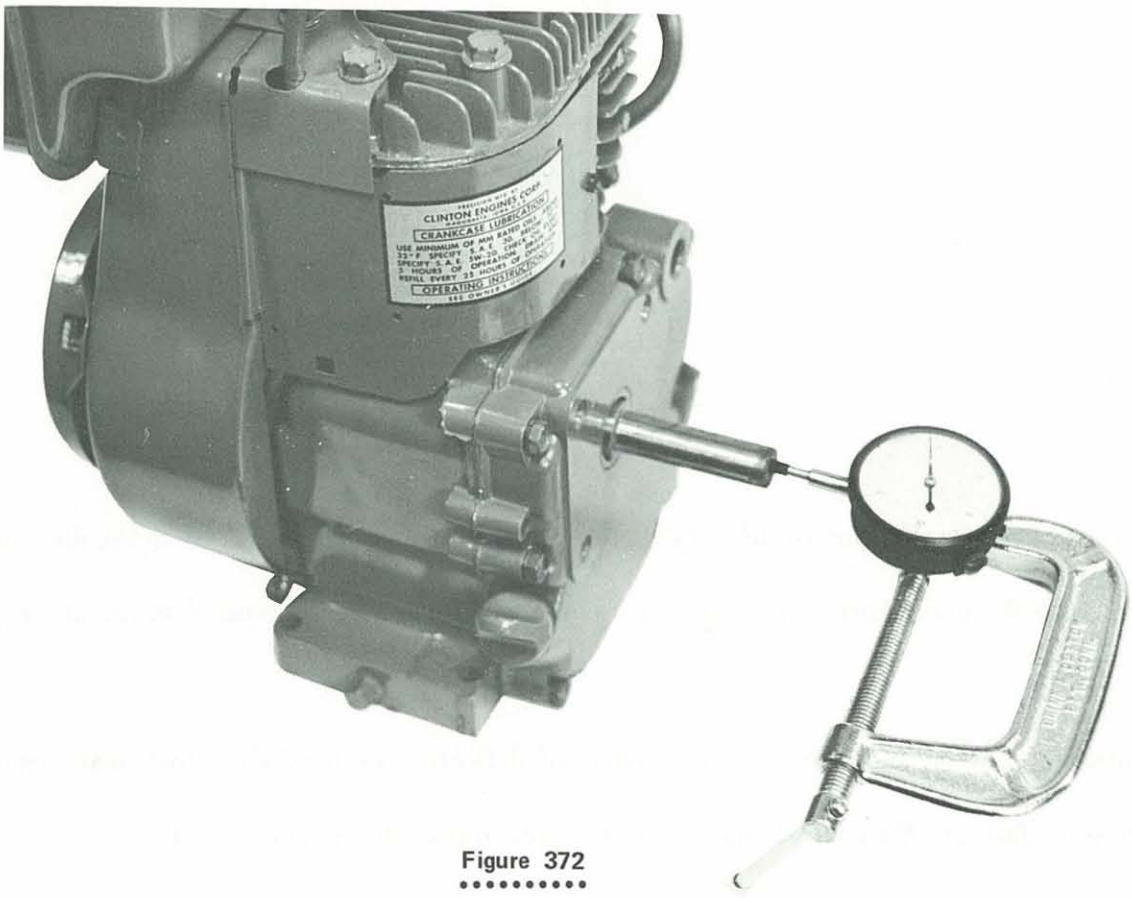

Figure 372

CRANKSHAFT OIL SEAL REPLACEMENT

Oil seals are used to prevent oil from leaking out of the crankcase on 4-cycle engines. Since the crankshaft extends through both sides of the engine housing, it is necessary to provide some sort of seal between the rotating crankshaft and the stationary engine housing to prevent oil from leaking out each end.

Seals in 2-cycle engines are used to keep the fuel, air and oil mixture from leaking out of the crankcase.

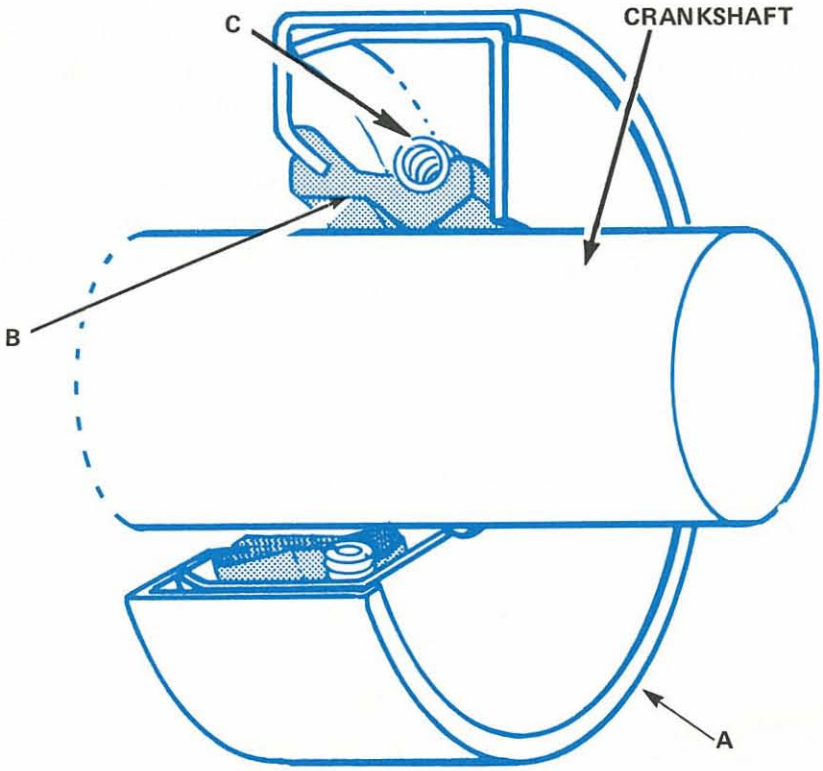

Figure 373

A typical oil seal used in many small engines is shown in Figure 373. Basically, all seals consist of a sleeve, shown at A, that is pressed into the stationary part, which is the engine housing. There is pliable part, or seal, shown at B, which is sealed to the sleeve and held against the crankshaft by some sort of spring tension as shown at C. Some seals have one pliable part or seal at one face. Others may have two seals, one facing in each direction. When a seal with a single lip is being installed, it is important that it is installed in the same direction as the original seal.

When the seal is inserted into the recess in the crankcase the pliable lip or wiper, must not be deformed or torn. The seal must be inserted square. Many shops use seal installation tools as shown in Figure 374. First the seal, shown at A, is slipped over the tapered end of the insertion tool shown at B. The insertion tool is hollow and made to fit directly over the crankshaft and into the seal recess. The seal driver, shown at C, fits directly over B, and against the seal so it will drive the seal in straight and square.

Seal installation tools are not absolutely necessary but make the job much easier. Any type of hollow driver, such as a piece of pipe or tubing, the proper size can be used to install seals if you are careful to drive them straight.

Old seals are removed by using a punch, chisel or other sharp instrument to cut into the sleeve and pry up. Care must be taken not to damage or scratch the crankshaft. The crankshaft must be cleaned of rust and build-up before installing new seals or the pliable lip will be damaged. Oil seals are not reuseable and should always be replaced with new ones.

Seals are used on both ends of the crankshaft on both 4-cycle and 2-cycle engines and should always be inspected for evidence of leaking. Some seals are held with a lock ring that must be removed before the seal can be taken out. Always apply a small amount of oil to the flexible part of the seal before installing. Some oil seals are installed inside the housing before it is installed over the crankshaft. These are driven in with a driving tool or piece of pipe about the same size as the sleeve of the oil seal.

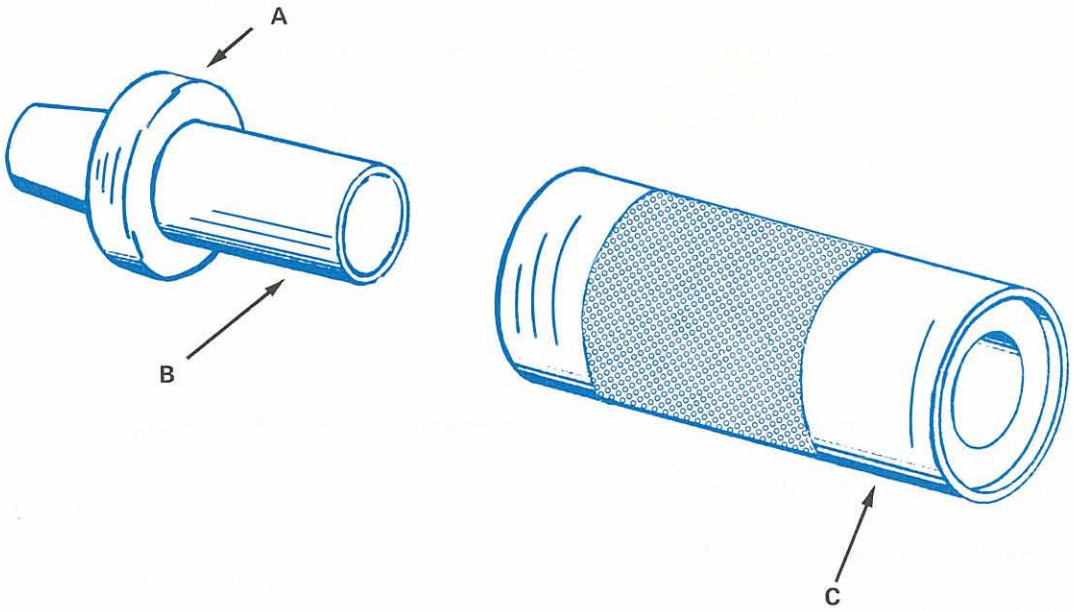

Figure 374

CRANKSHAFT REMOVAL

The first step in removing the crankshaft of a 4-cycle engine is to prepare the engine for removal of the piston and rod assembly, as we covered earlier. Remove the flywheel and breaker point assembly so this end of the crankshaft is free. Remove the crankcase or cover housing as shown in Figure 375. Relieve tension on valve springs, and set timing marks on crankshaft and camshaft gear to line up by turning crankshaft until both are aligned.

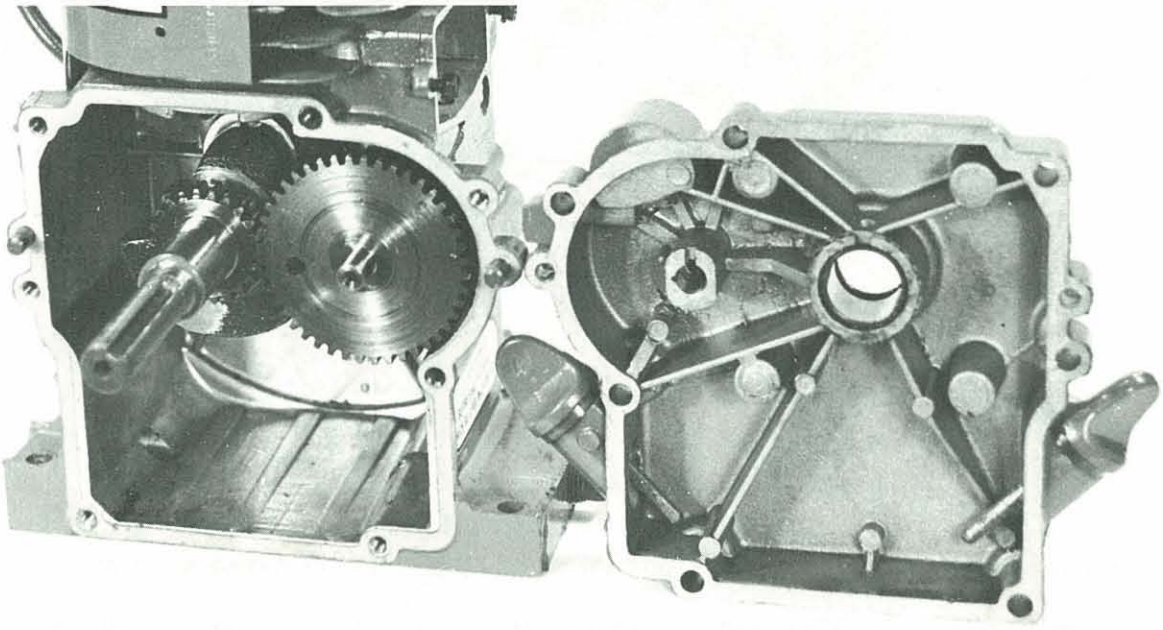

Figure 375

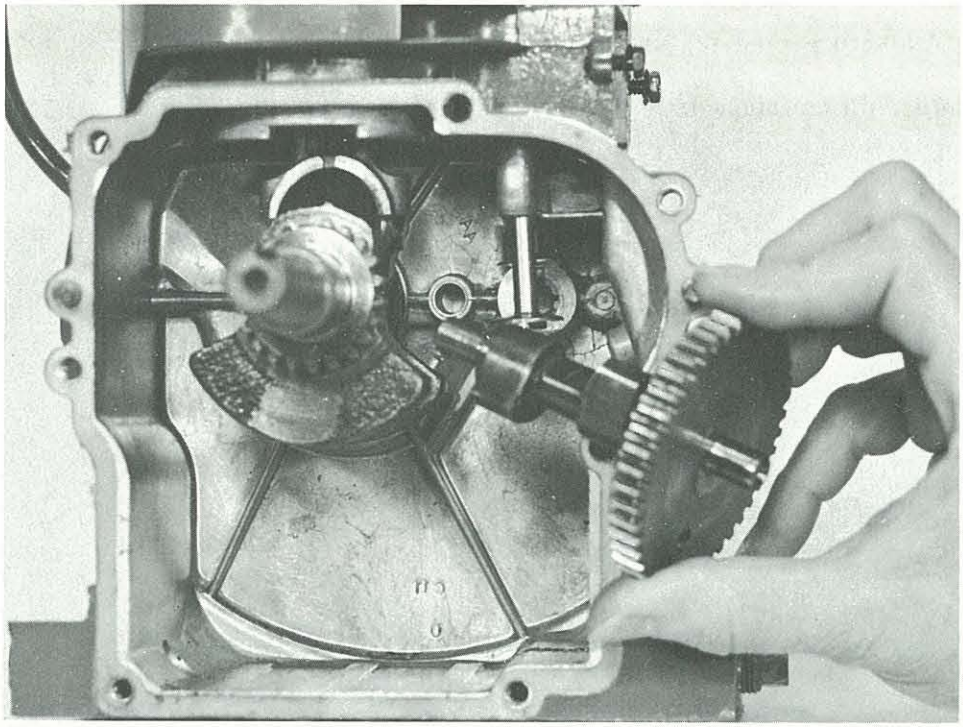

Figure 376

With tension released on the valve lifters, pull the camshaft gear out as shown in Figure 376. Try to position the engine so the valve lifters will not fall out. If at all possible, they should be replaced in the same position. After you have the camshaft removed, the crankshaft can be pulled straight out. This procedure would be the same for both vertical and horizontal shaft engines.

The procedure for removing the crankshaft from 2-cycle engines is very similar. First the piston and rod assembly has to be removed, by removing the carburetor and reed valve assembly, as shown in Figure 377. After the rod and piston have been removed, the cover plate, shown at A, is removed and the crankshaft can be lifted straight out.

There are a number of variations in the design of different engines that will change these procedures of crankshaft removal but these are the basic steps that can generally be applied to most small engines. Always be sure the crankshaft is clean and free of rust on both ends before sliding it through the oil seal. After the crankshaft is removed, check it carefully for defects as we covered earlier.

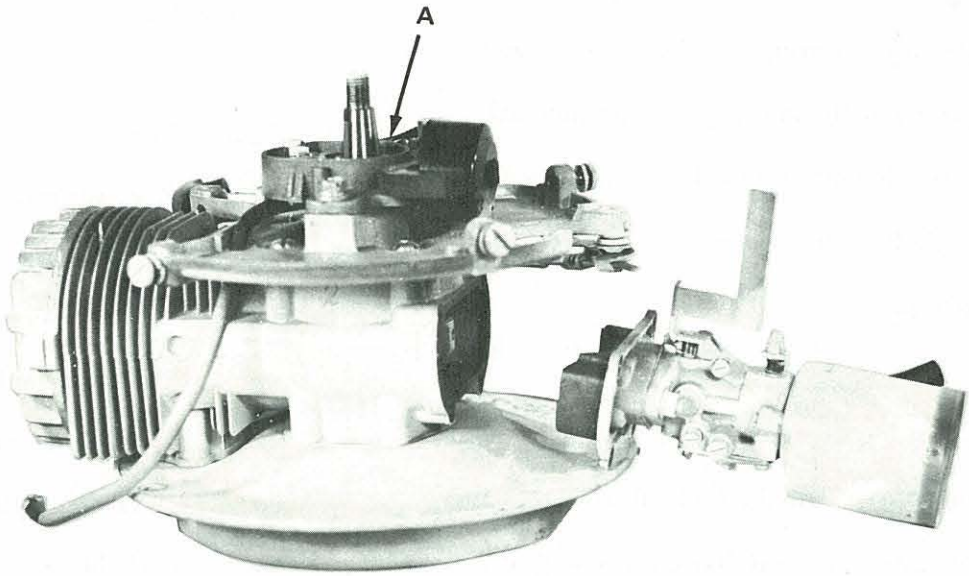

Figure 377

CRANKSHAFT BEARINGS

Do not remove crankshaft bearings unless necessary for replacement. There are generally two types of bearings used on most small engines. Plain sleeve bearings are still used on many small engines but the needle bearing type is becoming more popular. Some larger engines use roller or ball bearings. Clean the bearing and inspect for wear or damage. Caged bearings, such as needle bearings, should remain in their cage and not fall out. Check bearings to see if the outer race is turning in the housing. Check plain bearings for wear, scratches and scoring. When in doubt about the condition of any bearing it is best to replace it.

SHORT BLOCK

Before repairing the cylinder, piston and rod assembly, it is a good idea to check the crankshaft, bearings and valves. If many parts are worn it may be best to make the repairs by the "short block" method. The short block consists of a cylinder block, crankcase, crankshaft, camshaft, piston and rod assembly, bearings, gaskets, gears and valves, along with their related components. These are already installed and often will cost much less than replacing some of the individual parts.

Before getting further into short block replacements we should look at two things that any business must have, especially any small business. First the service mechanic has to make a reasonable profit. Second, he must satisfy his customers if he is to continue in business. The short block method of repair will fill both of these needs if an engine is in bad condition. The customer will have a better engine, more new parts and at less cost to him. The service mechanic will receive adequate compensation for his work and not have such a large investment in special equipment and tools for engine rebuilding.

Figure 378 (Page 19) shows an exploded view of a 4-cycle, vertical crankshaft short block engine, the same as used on many lawnmowers. Just the crankshaft, piston and rod assembly, if purchased separately would cost almost as much as the entire short block assembly. This complete unit, when ordered as a "short block assembly" is completely assembled and ready to attach the other parts of the engine, such as the magneto, flywheel, carburetor and exhaust system.

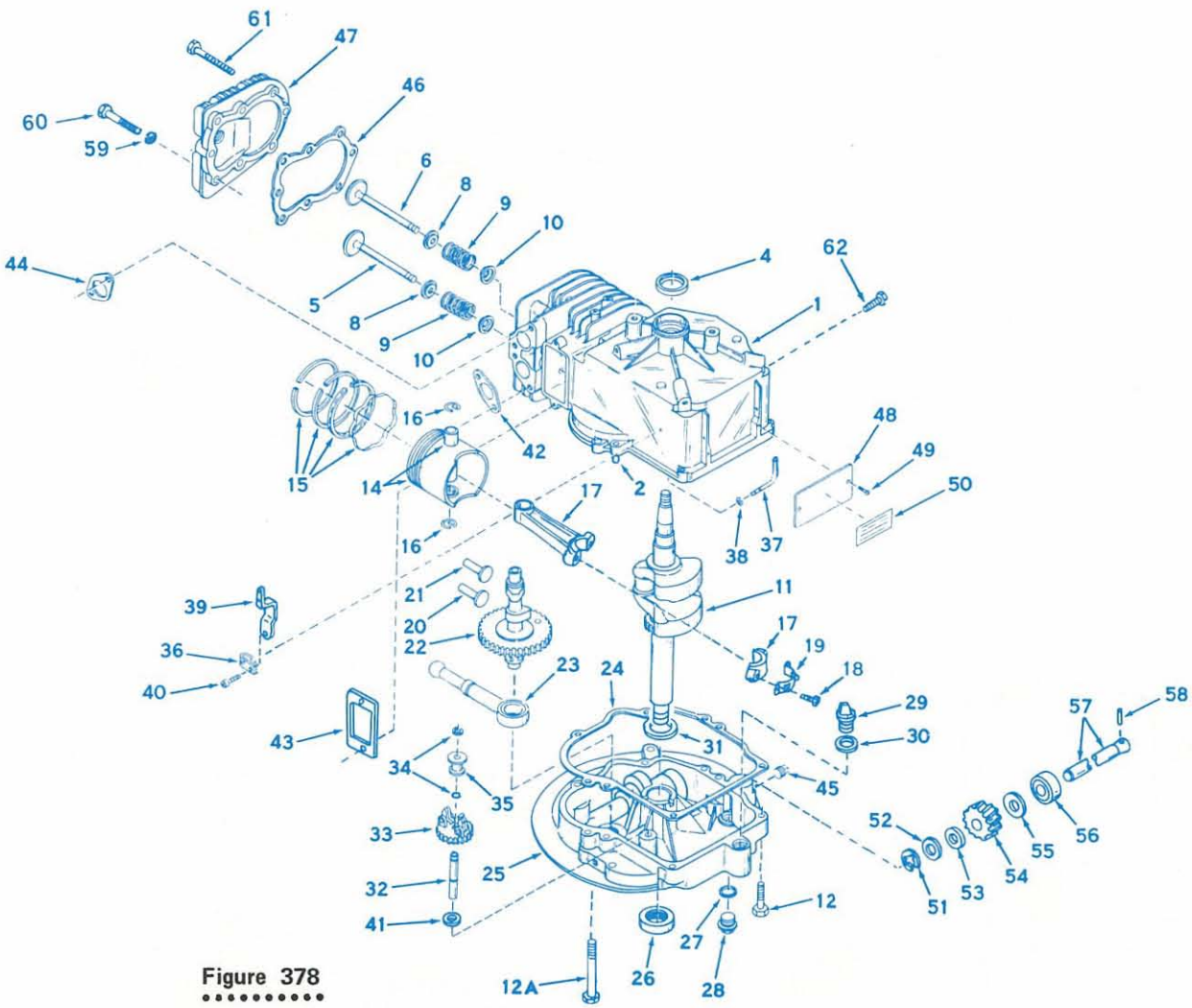

Figure 378

If a major overhaul is required the labor time would be about three hours, compared to installing a short block in a little over one hour. The cost to the customer would be about 25% less and he would have an engine with most of the wear parts in new condition. In addition to his labor charge, the service mechanic would make some extra profit on the short block assembly, since he buys them at a service dealer's discount.

A short block is actually nothing more than a new engine without the electrical equipment, starter, carburetor, shrouds, gas tank, exhaust and control linkages. All of these are removed from the old engine and installed on the short block.

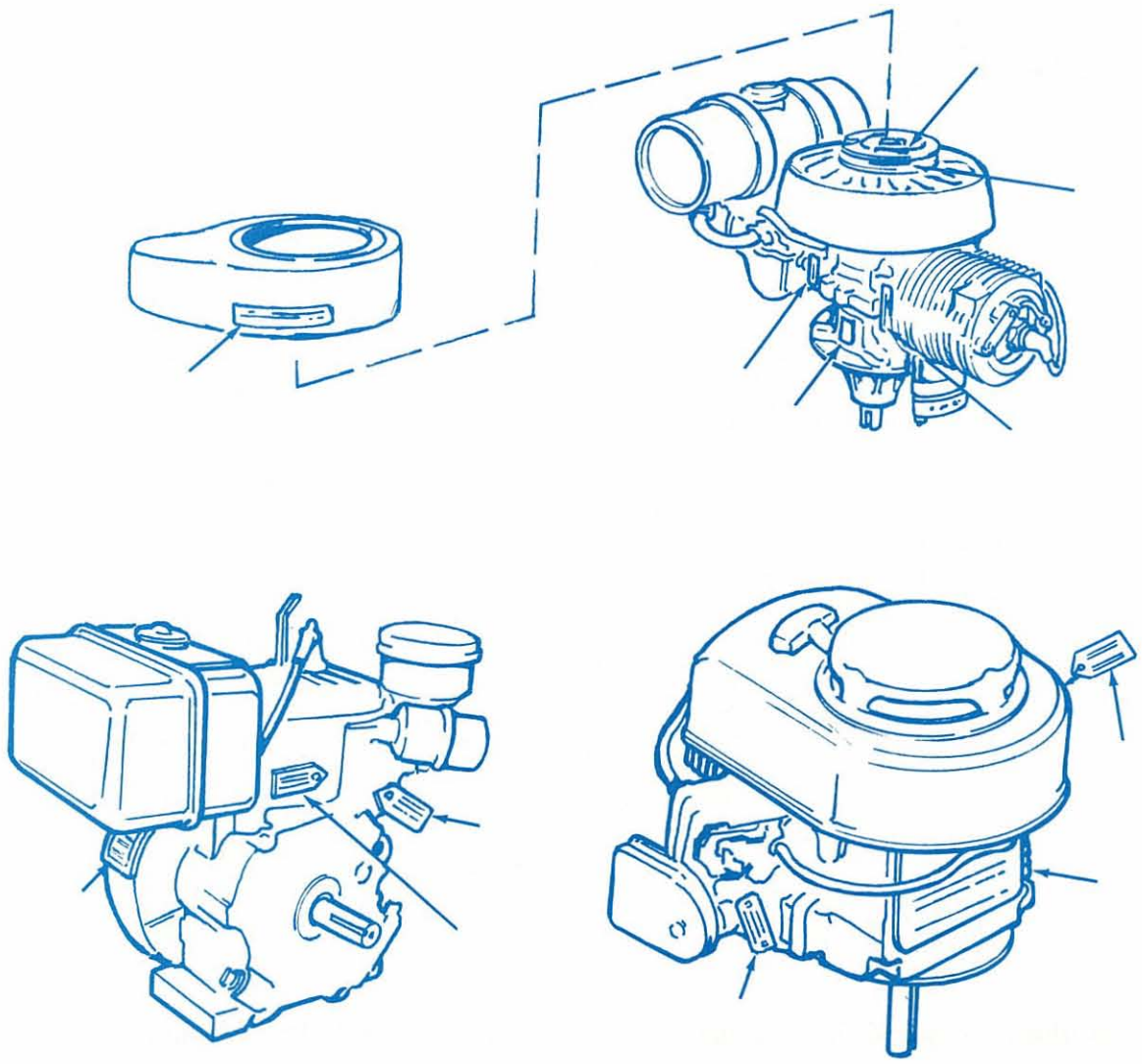

Figure 379

When ordering replacement parts or a short block always give your service distributor complete information on the engine. First identify whether it is 2-cycle or 4-cycle, whether it is a vertical or horizontal shaft and the horsepower. The necessary information you should give to your service dealer is given on the name plate or tag attached to the engine. Figure 379 shows some of the different locations these identification plates may be found. Look the engine over carefully. Some identification may be stamped on some part of the engine block or other part. To avoid mistakes, give him all the information possible, including crankshaft diameter and length.

This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
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LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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EXAMINATION ON LESSON 36
MAJOR OVERHAUL AND SHORT BLOCK

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INSTRUCTIONS:

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(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence Forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. On the compression stroke of four cycle engines, the intake valve is _____ and the exhaust valve is _____. _____
   a. closed, closed
   b. closed, open
   c. open, closed

2. The basic function of the crankshaft is to convert _____ motion of the piston into _____ motion. _____
   a. reciprocating, rotary
   b. rotary, reciprocating

3. As the piston is going down on a four cycle engine on the intake stroke, the _____ valve is closed. _____
   a. exhaust
   b. intake
   c. neither of the above

4. On the exhaust stroke of a four cycle engine the intake valve is open and the exhaust valve is closed. _____
   TRUE
   FALSE

5. The camshaft assembly opens and closes the valves on a _____ engine. _____
   a. two cycle
   b. four cycle
   c. both of the above

6. Valves on a four cycle engine are open when the lifters are riding on the _____ part of the cam. _____
   a. low
   b. high

7. Before removing the camshaft, you should relieve pressure on the valve springs. _____
   TRUE
   FALSE

8. The action of the camshaft on a four cycle engine is directly related to the position of the piston at the time the valve is open or closed. _____
   TRUE
   FALSE

(Continued on page 2)

9. On most small engines the straightness tolerance of the crankshaft should be between _____ and _____. _____
   a. .001 - .003
   b. .002 - .004
   c. .003 - .006

10. The teeth of the crankshaft gear on a four cycle engine engages directly with the teeth on the camshaft gear. _____
    TRUE
    FALSE

11. On the power stroke of a four cycle engine the intake valve is _____ and the exhaust valve is _____. _____
    a. open, closed
    b. closed, closed
    c. open, open

12. The crankshaft is connected directly to the rod and piston. _____
    TRUE
    FALSE

13. Fuel enters the combustion chamber through the _____ on a four cycle engine. _____
    a. intake valve
    b. exhaust valve
    c. both of the above

14. The nine basic parts of a four cycle small engine short block are:

A Cylinder Block
B _____
C _____
D _____
E _____
F _____
G _____
H _____
I _____

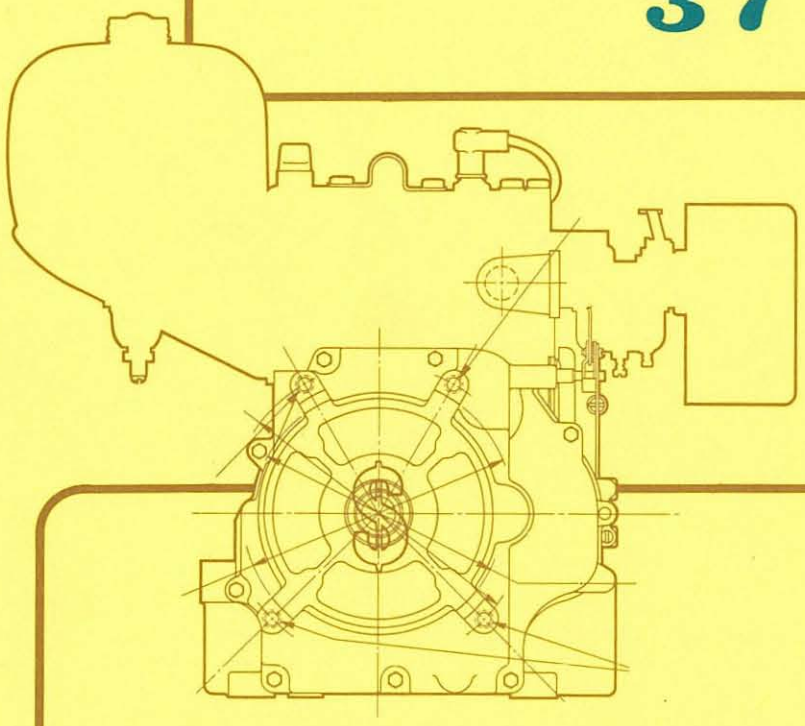
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

37



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LUBRICATION AND BREATHERS

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CRANKCASE BREATHERS

The purpose of the crankshaft breather is to allow crankcase pressure of 4-cycle engines to escape from the engine and to admit outside air back into the crankcase, without bringing dust and dirt back into the engine with the fresh air. The breather also helps maintain a slight pressure in the crankcase, removes gases and vapor and keeps out dust and dirt. Figure 380 shows the build-up of gases and crankcase pressure as the piston is on the down stroke. During combustion, a certain amount of blow-by from the combustion chamber passes by the piston rings and goes into the crankcase. If this blow-by, shown at A, was allowed to build up it will increase pressure in the crankcase to the point where oil seals and gaskets will rupture, causing oil leaks to develop.

This pressure is the result of both the downward motion of the piston and the blow-by. The gases and pressure caused by the downward motion of the piston are released by a valve in the area shown at B. This release of gas and pressure relieves the strain on the oil seals.

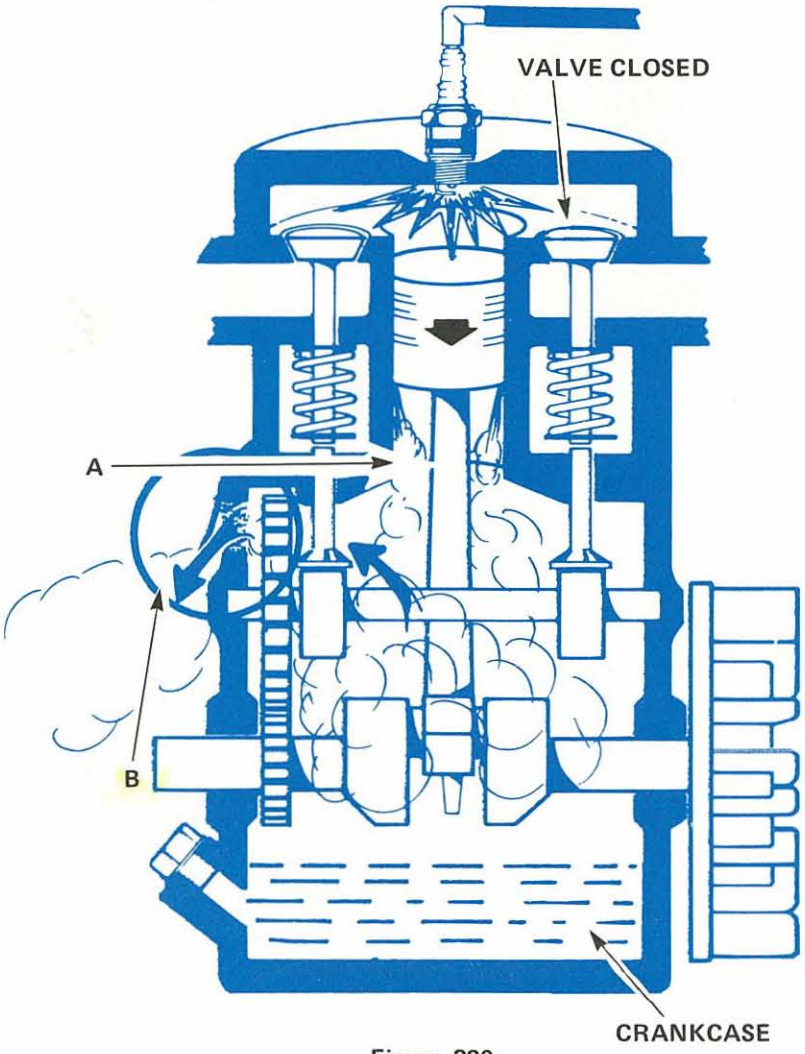


Figure 380

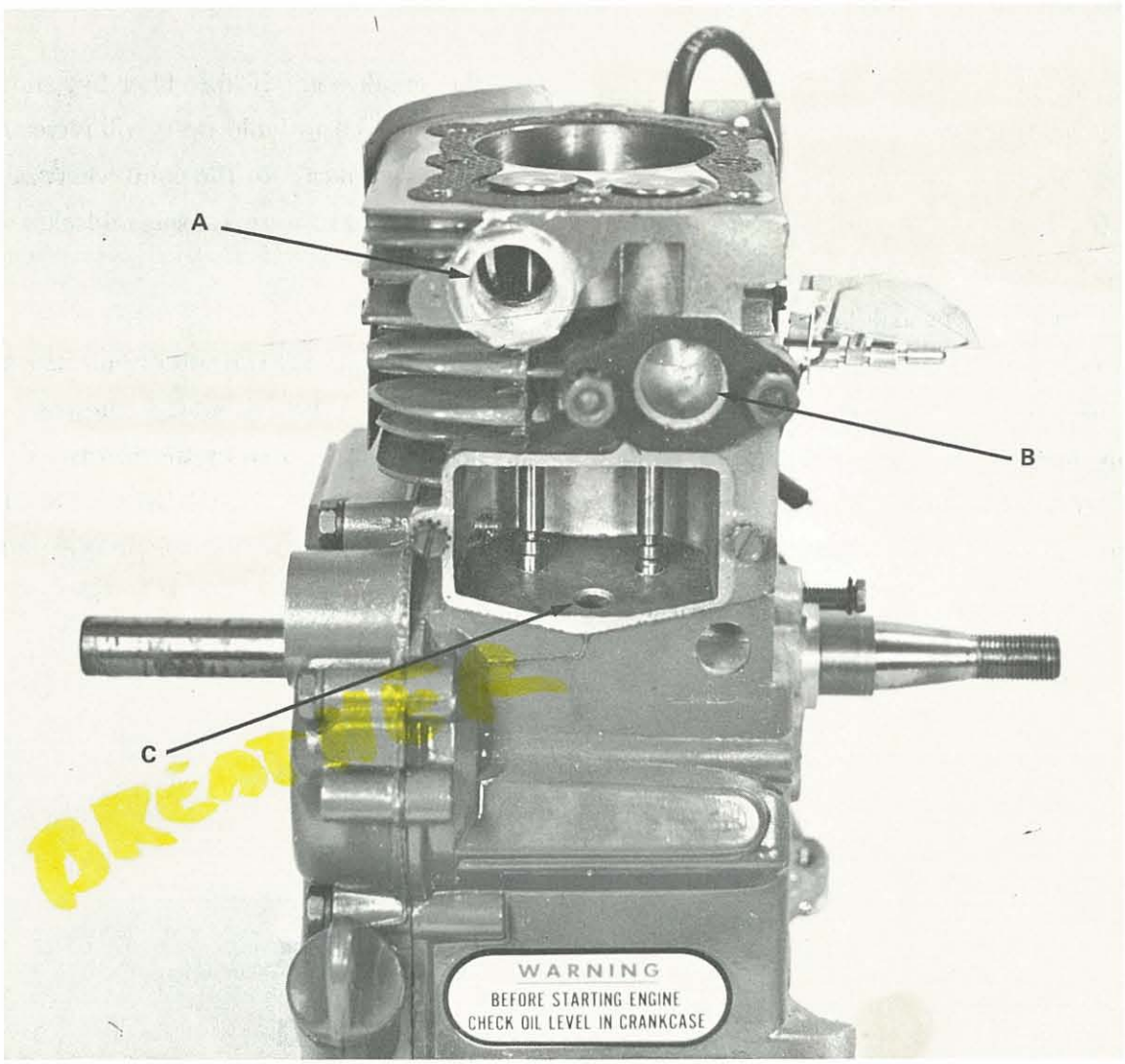


Figure 381

Crankcase breathers are only required on 4-cycle engines and are located in the valve access area shown in Figure 381. The exhaust is shown at A and the intake at B. There is an opening shown at C that goes direct to the crankcase. Excess pressure build-up in the crankcase is released through this hole into the valve access area. The valve access area is covered with the crankcase breather assembly which is actually a filter and a valve.

Figure 382 shows the basic principle of the crankcase breather. When the piston is on the down stroke pressure builds up in the crankcase. When this happens, the breather opens as shown at A. This relieves the pressure in the crankcase. When the piston is on the up stroke it creates a negative or low pressure in the crankcase and closes the breather valve as shown at B. To prevent dust and dirt from being drawn into the crankcase. The incoming air must pass through a filter shown at C. This prevents foreign matter from entering the crankcase.

There are a number of design variations in crankcase breathers but they all have the same function, to release pressure build-up inside the crankcase and filter outside air coming in. Some use a ball and check valve with a hose vented direct to the carburetor air filter. Others may use a coil type spring or floating disc instead of a leaf spring but their purpose is the same.

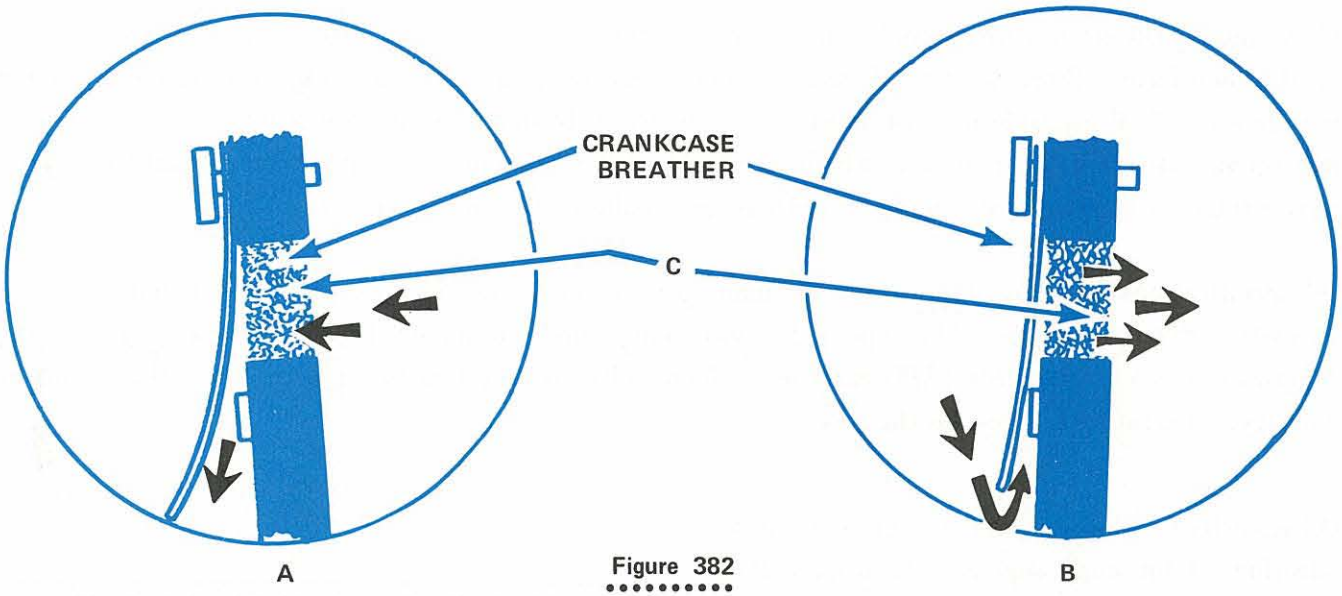


Figure 382

The important thing in checking breathers is to be sure the filter is clean and valve is free to work without sticking. The breather should be soaked in petroleum solvent, such as kerosene or diesel fuel and then dried at least once each operating season or oftener if the engine is operating under dusty conditions. If the outlet passage becomes clogged, excessive pressure builds up in the crankcase, oil seals and gaskets become ruptured and oil leaks develop.

If the inlet passage becomes clogged air can get out but not in. Too much negative pressure will develop inside the crankcase. This will cause strain on the oil seals and permit them to develop leaks that can draw fine dirt into the engine.

LUBRICATION

Oil is necessary for the proper operation of any engine. Without lubrication the moving parts will freeze and burn out. The better the lubrication system, the more power the engine will develop and engine life will be greater.

Oil reduces friction between moving parts by providing a cushion between them. Heat is reduced by having less friction and oil keeps dirt suspended so it is removed when the oil is changed. Oil prevents corrosion and provides a seal between the piston rings and the cylinder wall to prevent blow-by.

Small engines are not as well protected as most large engines because few of them have oil filters. This requires the oil to be changed more often to remove the metal particles, dirt and sludge that an oil filter would remove.

Since most small engines are air cooled, oil will run hotter than water cooled engines. This causes the oil to break down faster. Since most small engines operate near the ground, they are subject to dust and dirt and the amount of oil available in most small engines is relatively small. More wear is expected of an engine that operates for short intervals and at high speed. All of these together make it very important to properly service the oil system of small engines in order to get maximum life and efficiency.

Oil specifications are generally given on the name plate of most engines. Specifications include type and viscosity. Figure 383 shows the type and service conditions recommended for most small engines. The American Petroleum Institute (API) classifies different oils with a rating that is common in the petroleum industry. This rating is known as the type.

Oil viscosity is also important to consider when selecting oil for small engines. Viscosity is the resistance to flow, and is rated in SAE numbers, such as SAE 20. The lower the number the less resistance the oil has to flow. An oil having a rate of SAE 40 would have more of a resistance to flow than one having a lower rating.

Oil companies are now using multi-viscosity oils that permit using almost the same oil summer and winter. The oil may be labeled SAE 10 W-30, which means it has the capacity to lubricate the same as SAE 10 or SAE 30. Most small engine manufacturers recommend SAE 30 above 32 degrees F and SAE 10 below 32 degrees.

CRANKCASE OIL CLASSIFICATIONS

TYPE	SERVICE CONDITIONS
ML (Motor Light)	Service typical of **engines** used under light and favorable operating conditions, not recommended for most small engines.
MM (Motor Moderate)	Service typical of **engines** used under moderate to severe operating conditions.
MS (Motor Severe) or SC or SD	Service typical of **engines** used under unfavorable, or severe, types of operating conditions.

Figure 383

The lubrication systems for 4-cycle and 2-cycle engines are entirely different. The 2-cycle engines are lubricated by oil that is mixed with the fuel. The fuel and oil pass through the carburetor shown at A in Figure 384. Oil and fuel are pressurized in the crankcase when the piston moves down toward the crankshaft. This causes some of the oil to condense on the bearing surfaces. As the piston moves up, oil condenses from the mixture in the combustion chamber to lubricate the piston, rings and cylinder walls. All the necessary lubrication points shown in Figure 384 are lubricated from the oil in the fuel mixture.

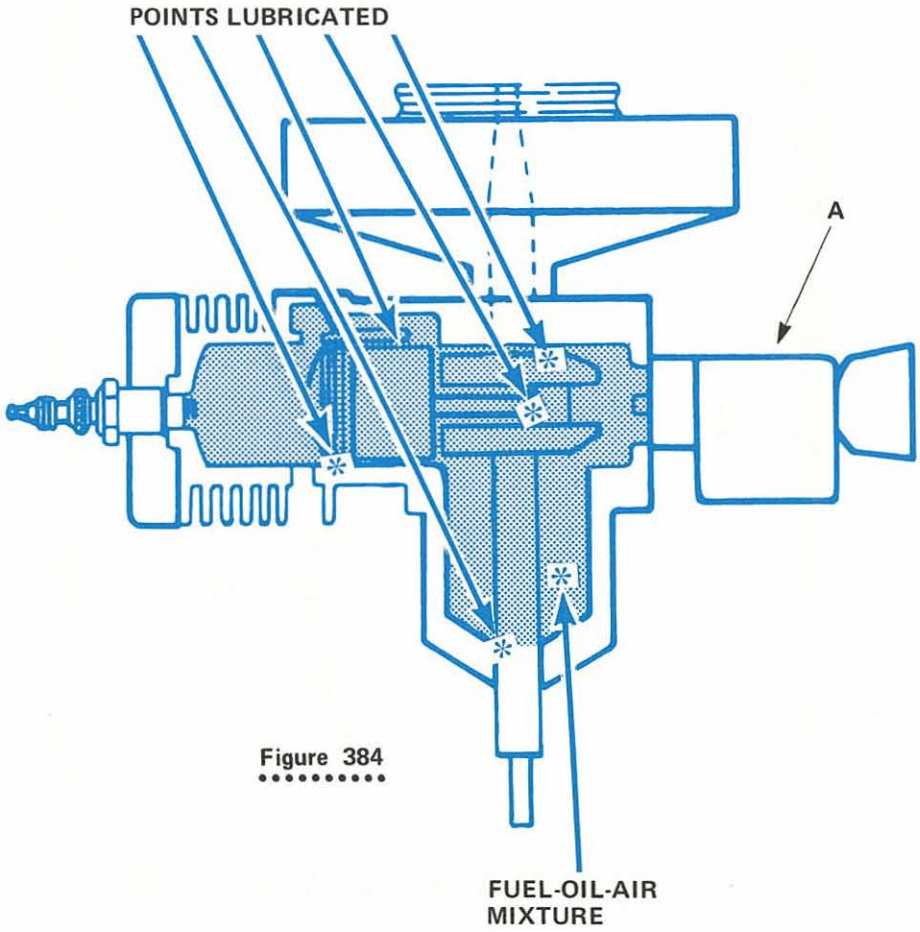


Figure 384

4-CYCLE LUBRICATING SYSTEMS

All 4-cycle engines have a separate oil supply and use some type of pump or splash method of distributing the oil around in the crankcase to all the necessary parts. Figure 385 shows a typical splash method used on many small engines. There is a dipper or scoop attached to the rod end of the crankshaft as shown at A. Each time the crankshaft turns the rod to the low position the dipper picks up oil and splashes it inside the crankcase. There is a continuous splashing of oil around the crankcase when the crankshaft is turning. Oil is also splashed onto the cylinder walls and lubricates the cylinder and rings. It is splashed onto the camshaft, cam gear and cam lobes. There are several other splash methods used but they all have the same basic function. They are designed to pick up and throw the oil all through the crankcase and cylinder wall area.

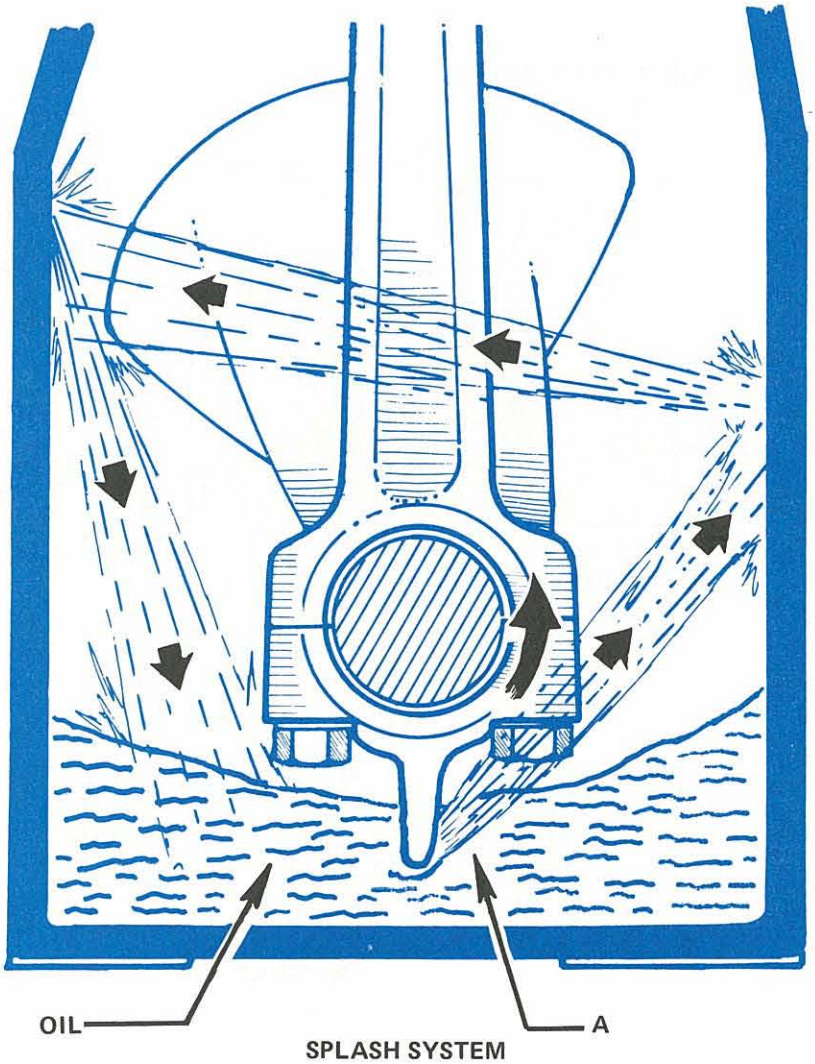
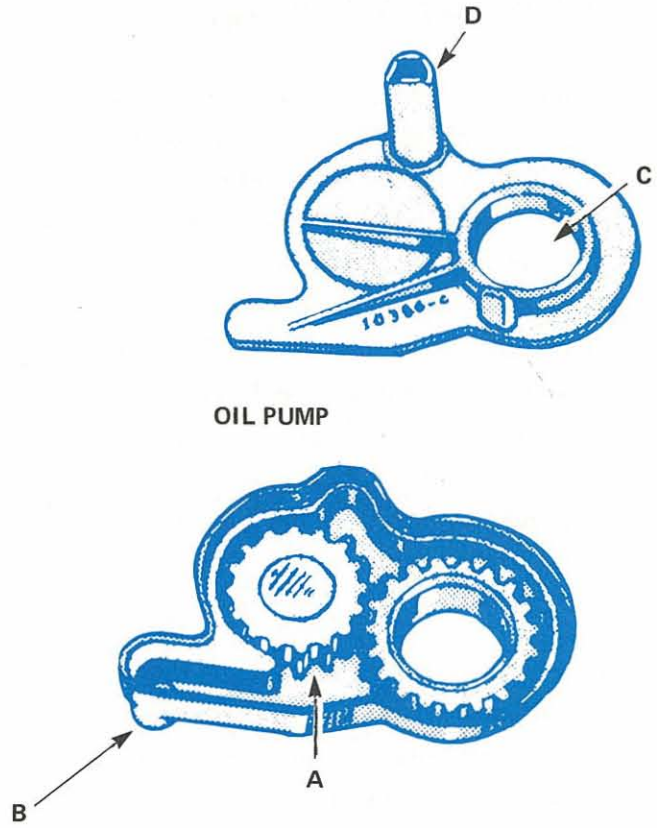


Figure 385

Figure 386 shows a gear-type pump. The drive gear, shown at A, is driven by the camshaft. The action of the two gears working together creates a pumping action and oil is picked up through an opening at B that goes direct to the oil sump. When the cover shown at C is in place the oil is forced out through the opening at D and to all necessary parts of the engine.



OIL PUMP

Figure 386

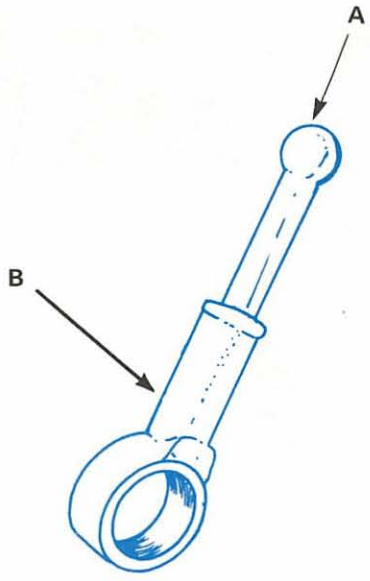


Figure 387

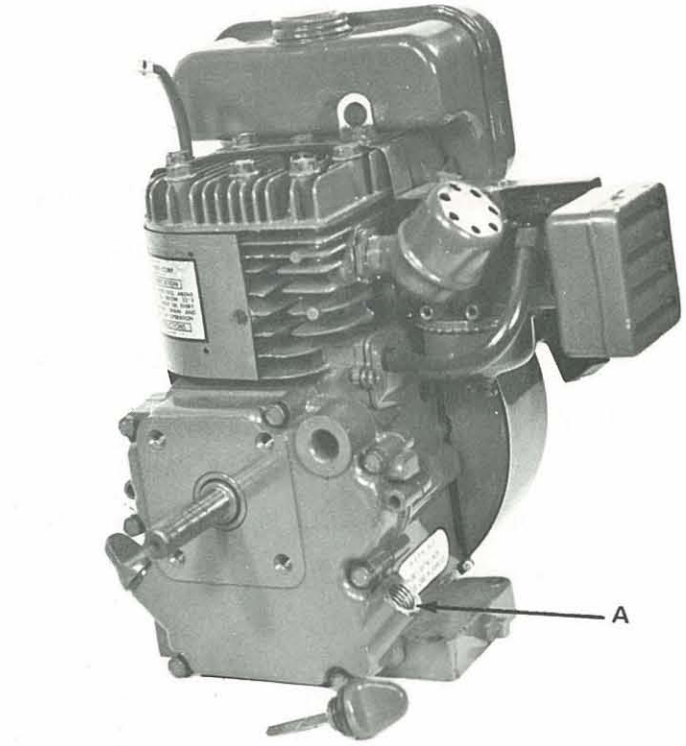
Another type that is very popular on small engines is the barrel and plunger pump shown in Figure 387. The plunger shown at A is held stationary in a recess of the engine housing. The barrel, shown at B, is operated from an eccentric drive located on the end of the camshaft.

CHECKING OIL AND PUMPS

Seldom will oil pumps cause trouble and you can generally tell from visual inspection if they are in bad condition. Slinger or other methods using the splash system will operate if they are installed properly. Always take notice of the direction they dip into the oil before removing. Gear pumps can be inspected for wear of the gear teeth and free turning on their shaft and housing. Any appreciable amount of play or looseness between the barrel and the plunger would indicate replacement of this pump.

Engine service shops should always advise their customers on oil recommendations and checking. Few operators will take the time to read the instructions on the engine specifications plate. Oil in 4-cycle engines should be checked every 2 to 4 hours of operation, depending on operating conditions. A good policy is to check the oil level every time the engine is refueled.

Figure 388 shows typical locations of the oil filter plug or drains. Sometimes there may be more than one drain hole or filler on the same engine, due to the mounting position on the equipment. The filler hole shown at A is maintained full of oil to the top. Fill until it begins to run over. The filler hole shown at B should also be filled all the way to the top. Many small vertical shaft engines used on lawnmowers may have two drain holes as shown at C and D. When these engines are mounted on lawnmower bases there is generally a hole in the base so the oil can be drained from the bottom.



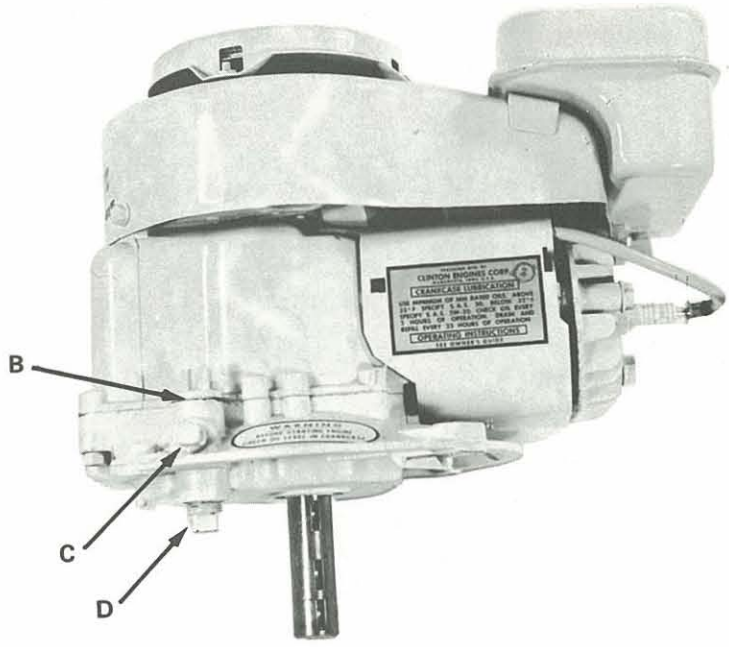


Figure 388

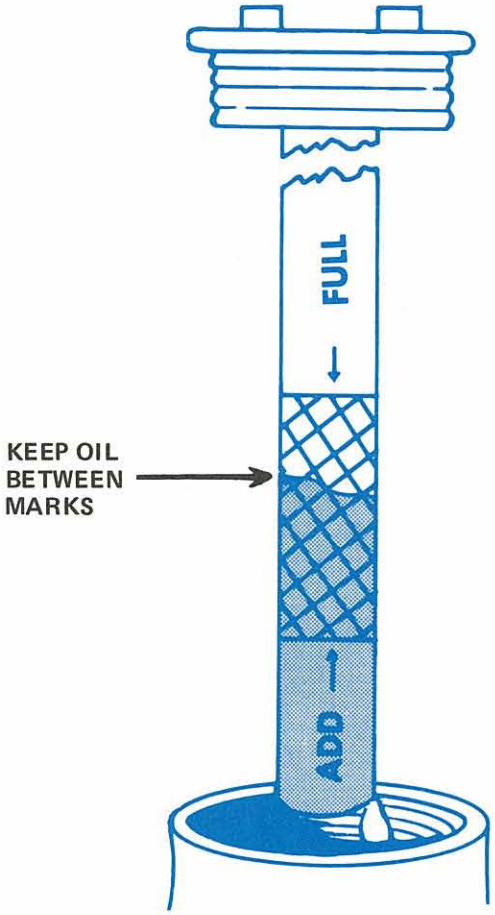
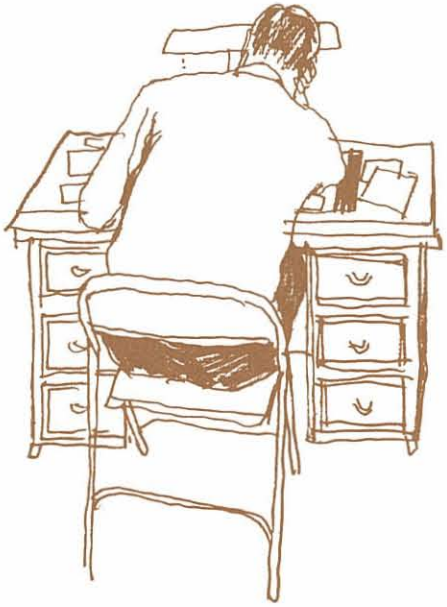


Figure 389

Some engines will be equipped with a dipstick attached to the filler plug, as shown in Figure 389. These are marked showing the full and safe operating range. If below the full mark it is a good idea to change the oil if it appears thick or dirty.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAMINATION ON LESSON 37
LUBRICATION AND BREATHERS

FOLEY-BELSAW INSTITUTE OF
SMALL ENGINE REPAIR
6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

NAME _____ Student No. _____

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Oil will deteriorate faster in water cooled engines than air cooled engines. _____
   TRUE
   FALSE

2. If blow-by is allowed to continue, it will damage the oil seals and gaskets. _____
   TRUE
   FALSE

3. Fuel and oil passes through the carburetor on _____ engines. _____
   a. two cycle
   b. four cycle
   c. neither of the above

4. When the piston on a four cycle engine is on the down stroke, it _____ the valve in the crankcase breather. _____
   a. closes
   b. opens
   c. neither of the above

5. The main purpose of the crankcase breather on a four cycle engine is to allow crankcase pressure to escape and to admit outside air back into the crankcase. _____
   TRUE
   FALSE

6. When the piston on a four cycle engine is on the up stroke, it _____ the valve in the crankcase breather. _____
   a. opens
   b. closes
   c. neither of the above

7. Oil viscosity is the resistance to the flow of oil. _____
   TRUE
   FALSE

8. During combustion, blow-by from the combustion chamber passes by the piston and rings of a four cycle engine and goes into the crankcase. _____
   TRUE
   FALSE

(Continued on page 2)

9. When the piston is on a down stroke on a four cycle engine, pressure builds up in the crankcase area. _____
   TRUE
   FALSE

10. Oil labeled SAE 10 has a higher viscosity than one labeled SAE 40. ____
    TRUE
    FALSE

11. Excess pressure buildup in the crankcase area on a four cycle engine is released through the valve access area.
    TRUE
    FALSE

12. Crankcase breathers are used on both two cycle and four cycle engines. _____
    TRUE
    FALSE

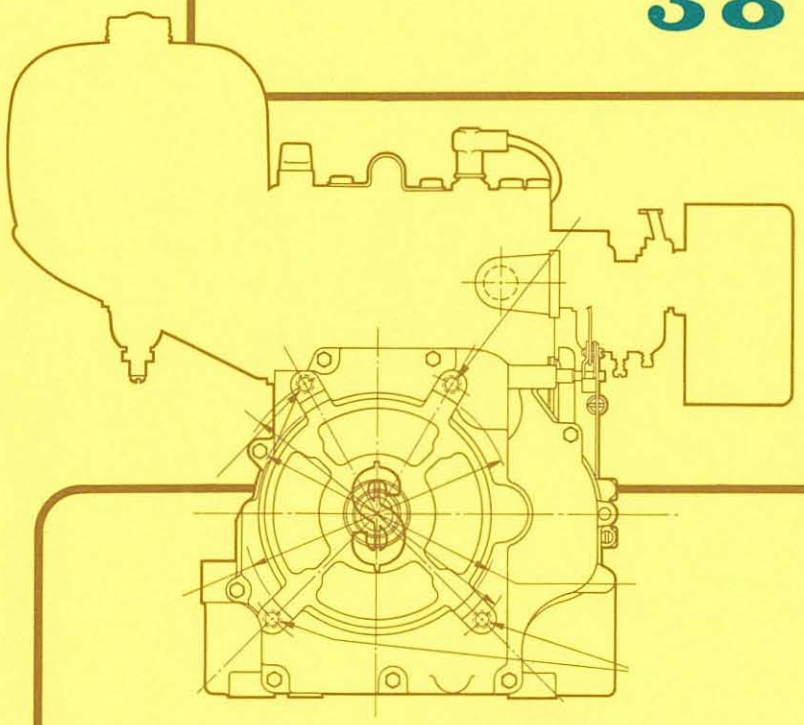
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

38



TURN THIS PAGE

...and let's find out all about -- PARTS CATALOG AND TROUBLE SHOOTING

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PARTS CATALOG READING

Looking up and identifying engine parts is similar when working with different engine catalogs. Some are more complicated than others, however, they all follow along the same line. Earlier we covered some of this in one of the lessons on exploded view drawings. Now we'll go more into detail with an example of one of the larger engine manufacturers. These are just examples and do not necessarily apply to any specific engine.

Figure 390 (on page 2) shows an exploded view drawing of an engine carrying Model BEL 6642. This is a complete listing of all the parts of this engine, except it does not show a breakdown of the parts of the carburetor, magneto or starter. This drawing shows them as complete assemblies which means it is available only as an assembly, or shown in a separate drawing.

If you will notice, there are two carburetors listed. One is shown at 204 and the other is 204A. This same basic engine may be equipped with either of these carburetors. The magneto shown at 205 does not show a breakdown of the individual parts. There is only one shown. The parts will appear on another drawing. There are five starters listed, 206, 206A, 206B, 206C and 206D. Any one of these five starters may be used on this same basic engine.

Starting with the carburetor, the first thing you have to decide is which one of the two carburetors shown at 204 and 204A is the type used on the engine you are working on. There is only one magneto shown. Next, you have to decide which of the starters shown is like the one used on your engine.

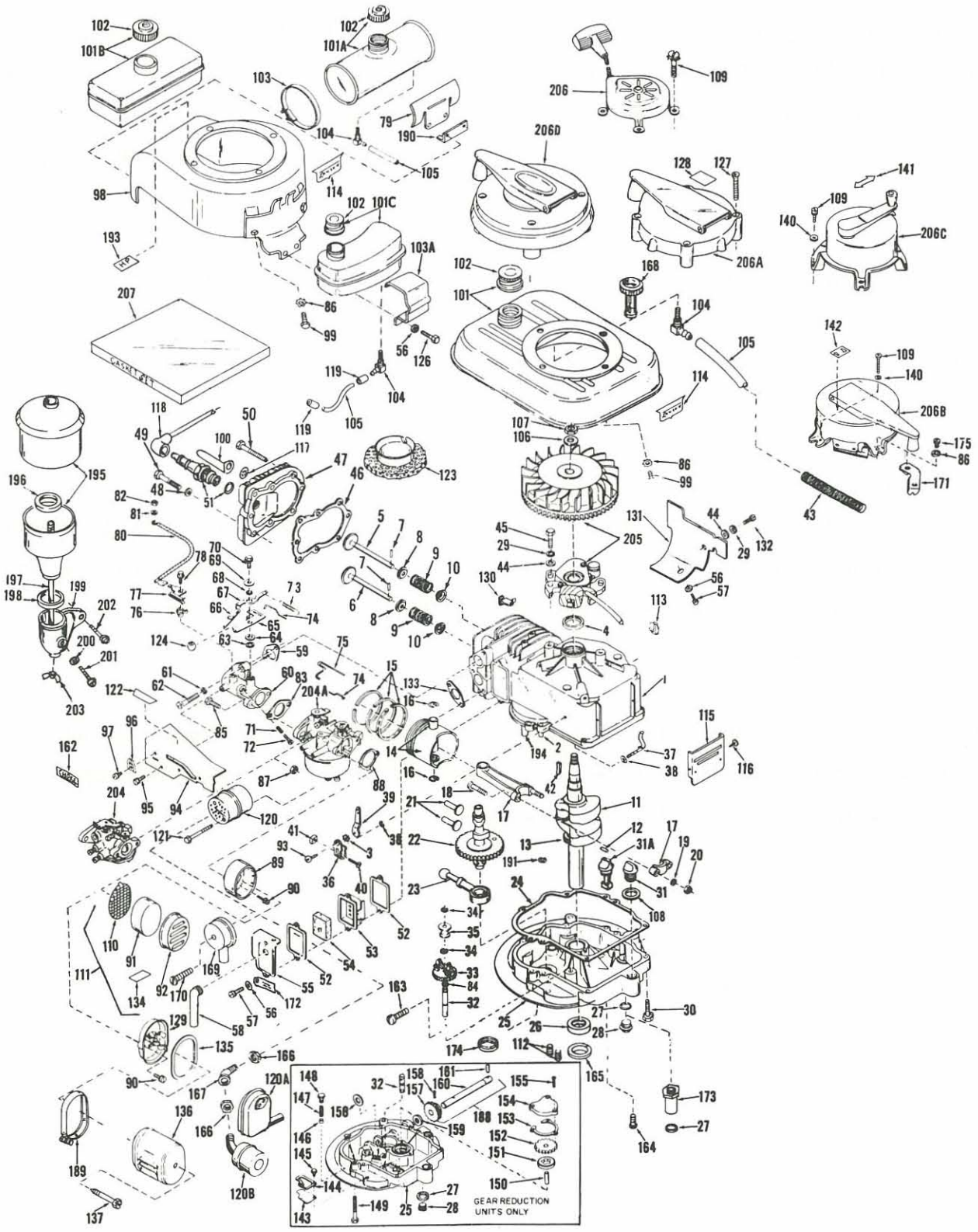


Figure 390

Earlier when we studied exploded view drawings we found the reference number always tells the part number and part name. If the carburetor is Ref. No. 204A, the magneto is 205 and the starter is 206, the part numbers may be like those shown in Figure 391.

Ref. No.	Part No.	Part Name
204A	63497	Carburetor
205	61275	Magneto
206	54320	Starter

Figure 391

To locate the parts needed for carburetor 63497 we look up this carburetor number under the carburetor section of the parts catalog. Figure 392 shows an exploded view drawing of all the parts used in this carburetor. Notice there are three choke levers shown at 4, 4A and 4B. Different engines may use any one of these three parts.

If parts are needed for the 205 magneto they would be shown under part No. 61275. The 206 starter would be found under 54320. Other than the basic engine; the carburetor, magneto, and starter parts breakdown will generally be found in separate exploded view drawings. Sometimes these drawings will be on the same page as the complete engine but will be in a separate box at one side.

CARBURETOR NO. 63497

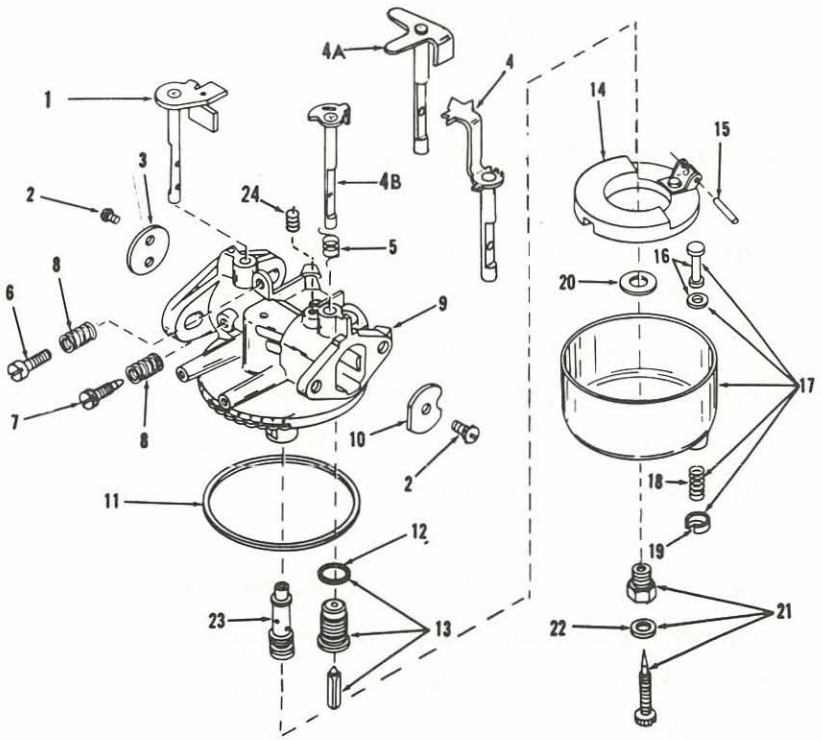


Figure 392

MICROFICHE

Small engine catalogs are becoming larger and more bulky due to new engine designs and changes introduced each year. Lawson Power Products who manufacture the Tecumseh engine has one of the larger catalogs due to many different makes and models produced. Because these parts catalogs are becoming bulky, some of the larger engine manufacturers have been converting over to microfiche. Each page is photographically reduced to approximately 5/16 by 1/2-inch. This permits putting 98 pages on a small piece of film.

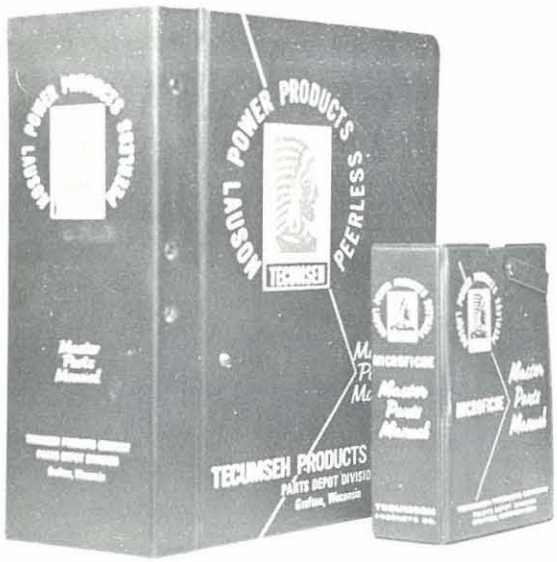


Figure 393

Figure 393 shows the complete Lawson Power Products parts catalog that contains hundreds of pages and is quite heavy and bulky to use. The small microfiche catalog next to it weighs less than one pound and contains all the information in the large catalog. Parts can be located in just a fraction of the time with the microfiche system.

BRAND UNIT IDENTIFICATION

There are four major manufacturers that produce about 90% or more of the small engines used on lawnmowers and other small engine applications. Briggs & Stratton make only the 4-cycle engine and probably have the largest volume of an individual 4-cycle engine brand name.

Lawson Power Products, which makes the Tecumseh engine, is the largest individual supplier of both 2-cycle and 4-cycle engines. Many of their engines and equipment may be identified under other names such as Craftsman, Eska, Lawson, Toro, Power Products and others.

Clinton makes both 2-cycle and 4-cycle engines for many different applications but retains the brand name.

Lawn Boy makes only 2-cycle engines and they are used on their own line of equipment. They are one of the few engine manufacturers who make their own equipment.

TROUBLE SHOOTING

To eliminate a lot of wasted time and dissatisfied customers we are listing a trouble shooting guide that can be used in analyzing engines brought in for service. By following these steps the necessary repairs can be diagnosed and made to that portion of the engine. Some service mechanics spend hours replacing parts on engines and, after they are finished, the engine will not perform satisfactorily.

The very first thing to do, is to isolate the trouble. In order for an engine to operate it must have compression, fuel and ignition at the magneto and spark plug. Check these first before you begin to look for the exact source of the trouble.

ENGINE FAILS TO START OR STARTS HARD	2-Cycle	4-Cycle
No fuel in tank	X	X
Fuel shut-off valve closed	X	X
Fuel line to carburetor blocked	X	X
Water or foreign matter in tank	X	X
Stale fuel in tank	X	X
Insufficient or no fire to plug	X	X
Spark plug fouled or defective	X	X
Stop switch in Off position	X	X
Engine flooded	X	X
Choke valve not completely closing	X	X
Carburetor idle needle or power needle not properly adjusted	X	X
Carburetor throttle lever not open far enough	X	X
Low Compression	X	X
Not cranking fast enough	X	X
Carbon blocking exhaust ports	X	
Broken reed valve	X	
Oil seals leaking	X	
Dirty Carburetor	X	X
Loose blade, vertical shaft engine	X	X

ENGINE MISSING UNDER LOAD OR LACK OF POWER		
Weak or irregular spark at plug	X	X
Defective spark plug	X	X
Choke not completely open	X	X
Carburetor idle or power needle not properly adjusted	X	X
Restricted fuel supply to carburetor	X	X
Valves not properly functioning		X
Stop switch not in positive On position	X	X
Spark plug wire loose or not connected	X	X
Dirty air cleaner	X	X
Insufficient oil in crankcase		X
Improper fuel mixture	X	
Too much load on powered equipment	X	X
Obstructed exhaust system	X	X
Weak valve springs		X
Reed valve assembly defective	X	
Crankcase gaskets leaking	X	

ENGINE NOISY OR KNOCKS	2-Cycle	4-Cycle
Piston hitting carbon in combustion chamber	X	X
Loose flywheel	X	X
Bad connecting rod	X	X
Main bearing worn	X	X

ENGINE SURGES OR RUNS UNEVENLY		
Fuel tank vent hole clogged	X	X
Carburetor float level set too low	X	X
Restricted fuel supply to carburetor	X	X
Carburetor power and idle needle adjustment	X	X
Governor parts sticking or binding	X	X
Carburetor throttle linkage binding	X	X

OVERHEATING		
Carburetor setting too lean	X	X
Improper fuel	X	X
Over-speeding engine	X	X
Running engine too slow	X	X
Overloading engine	X	X
Insufficient oil in crankcase		X
Improper fuel mixture	X	
Air flow to cooling fins obstructed	X	X
Dirty engine	X	X
Excess carbon in combustion chamber	X	X
Obstructed exhaust system	X	X
Engine out of time		X

ENGINE VIBRATES EXCESSIVELY		
Engine not mounted securely	X	X
Bent crankshaft	X	X
Driven equipment out of balance	X	X

REPAIR PARTS INVENTORY

There are basically 5 steps of distribution between the manufacturer and the small engine repairman. Replacement engines and parts are handled through one or more of these distribution steps. Generally the purchase quantities and business volume will determine which step of distribution you are able to buy through. These are the 5 basic steps used by some of the small engine manufacturers.

1. Factory ships direct to a central Warehouse Distributor.
2. Central Warehouse Distributor direct to a Service Distributor.
3. Service Distributor direct to a Service Dealer.
4. Service Dealer direct to small engine repair shop.
5. Small engine repair shop.

The Service Dealer is often one of the larger small engine repair shops doing enough repair business to buy direct from the Service Distributor. You will find the Service Distributor and Service Dealer nearest you listed in the telephone book yellow pages. They are generally listed under "Engines, gasoline".

Since it is not practical for the average small engine repair shop to stock parts for all the different makes and model engines the Small Engine Service Association has compiled a list of the fast moving parts for the leading engine manufacturers.

Since lawnmower engines and other similar engines up to 5 horsepower account for the bulk of the small engine repair business, you will generally be concerned with carrying repair parts in stock for four different engine manufacturers that produce the majority of engines for this field.

The four manufacturers and their estimated percentage of the total small engine business are:

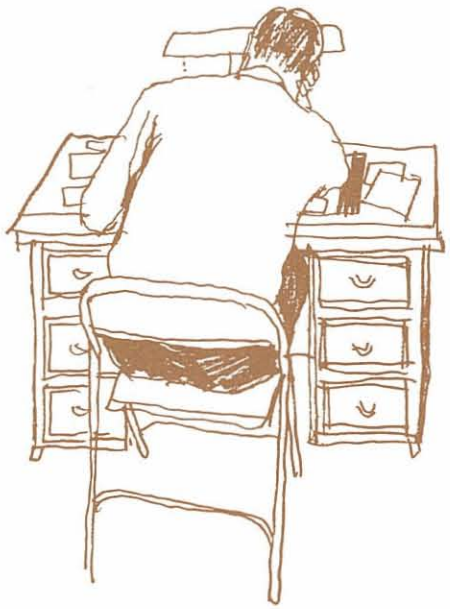
50% Briggs and Stratton
25% Lawson Power Products (Tecumseh)
15% Clinton
10% Lawnboy

These percentage figures can be used as a general guide in determining the parts you will want to carry in stock. These are only estimated figures and may vary in different parts of the country. After a short time in the small engine repair business you will begin to develop a pattern of the fastest moving parts that you will want to carry in stock. The majority of small engine repair work will consist of major and minor tune-up, cleaning and adjustments. This will require only a minimum number of the fast moving parts listed in the Quick Reference Parts Manual. The following condensed parts list should be adequate as a starting inventory. There are a number of duplication of parts that are used in both 2-cycle and 4-cycle engines made by Clinton and Lawson. The same part, such as the points #135-7-500 are used in both Clinton engines and the points #30547A are used in both Lawson engines. Starter springs, ropes, coils and other parts are often duplicated in both 2-cycle and 4-cycle engines produced by the same manufacturer.

MINIMUM INVENTORY CONDENSED PARTS LIST

	Briggs 4/cycle	Clinton 2/cycle	Clinton 4/cycle	Lawson 2/cycle	Lawson 4/cycle	Lawnboy 2/cycle
Points	- - - - -	135-7-500	135-7-500	30547A	30547A	677254
Condenser	- - - - -	135-29-990	135-29-990	30548A	30548A	677299
Breaker Assy.	299061	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
Spark Plug (*)	J8	J12J	H10	J17LM	J8	CJ14
Starter Rope	66694	246-7	246-7	590386	590386	604279
Starter Spring	294303	263-79	263-79	590414	590414	604257
Head Gasket	27670	94-670	94-107	510274 510265	29953B	604116
Air Cleaner Element	27987	2-225	2-225	450215	33006	602016 604274
Coil	298502	135-13-990	135-13-990	30560A	30560A	678539
Carb. Diaph.	270026	- - - - -	- - - - -	630978	690978	- - - - -
Carb. Repair Kit	291691	39-910	39-910	- - - - -	- - - - -	- - - - -
Carb. Needle & Seat	299059 299060	- - - - -	- - - - -	631505	631021	- - - - -
Engine Gasket Kit	297275	94-594	94-591 94-593	510295 510296	33236	678071
Carb. Repair Parts	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	605140 Nozzle 678882 Float valve & seat 604283 gasket 607637 screen 678414 primer Assy.

(*) Champion



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

(Fold Here)

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NAME_____
PLEASE PRINT

ADDRESS_____

CITY-STATE-ZIP_____

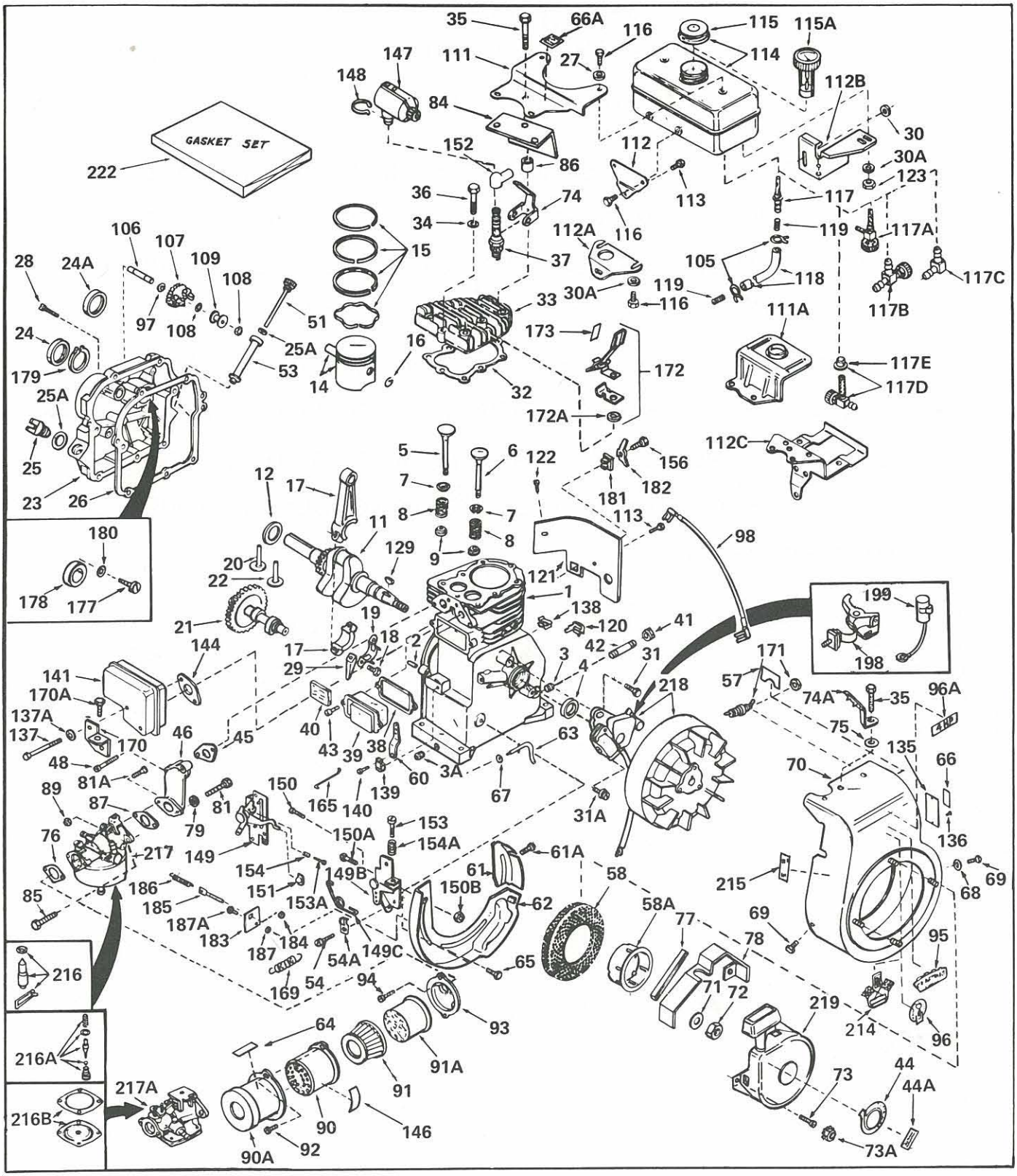
IMPORTANT!!
PLEASE READ THIS FIRST.

TECUMSEH ENGINE SUPPLEMENT.

SOME OF THE PICTURES THROUGHOUT LESSONS 39 THROUGH 42 WILL NOT MATCH YOUR TECUMSEH ENGINE EXACTLY. IN ORDER TO HELP YOU IN DISASSEMBLING AND REASSEMBLING, WE ARE ENCLOSING AN EXPLODED VIEW DRAWING OF THIS PARTICULAR MODEL. STUDY THIS DRAWING CAREFULLY, AND REFER BACK TO IT AS YOU ARE FOLLOWING THE STEPS IN DISASSEMBLY AND REASSEMBLING OF YOUR ENGINE.

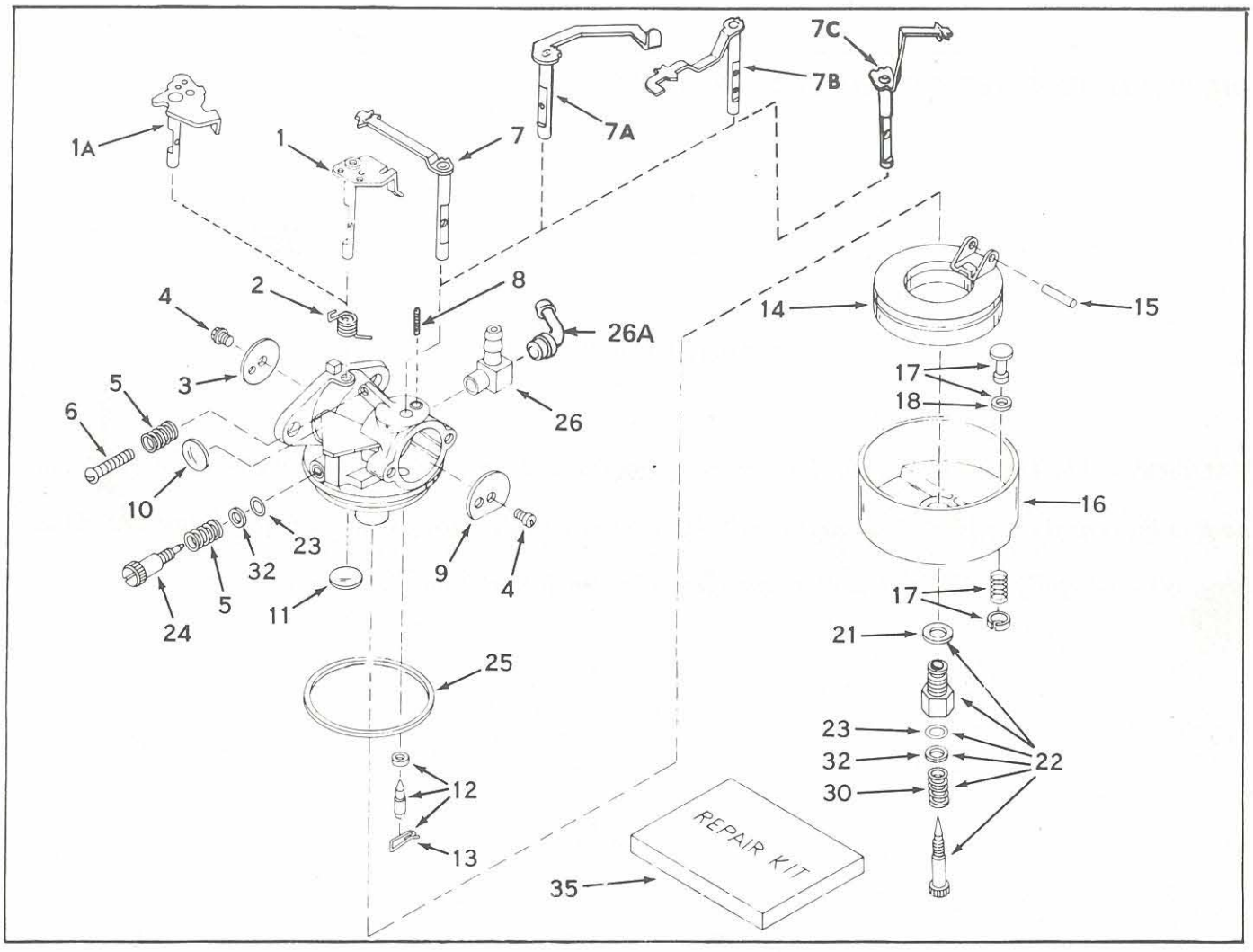
OTHER PARTICULARS ON THIS ENGINE ARE ALSO NOTED FOR YOU. PLEASE BE SURE TO READ OVER THESE BEFORE YOU START WORKING ON YOUR TECUMSEH ENGINE.

LAUSON MODEL HS40



CARBURETOR DISASSEMBLY AND REASSEMBLY

Lesson 41 will cover carburetor servicing. The float carburetor on your Tecumseh engine is very similar to the one outlined in this lesson. However, there are some minor variations. An exploded view drawing of this particular carburetor is shown below. Study this carefully for a few moments, and be sure to refer back to it as you are working on your carburetor.



AIR FILTER

The air filter on this particular unit is a dry paper element type. To clean this type of filter, tap it slightly on your workbench to loosen dirt, or blow from the inside out with "LOW" pressure air. This filter can also be washed gently in a soap and water solution as long as you thoroughly flush or rinse the element free of any excess soap. Allow the element to completely dry before you reinstall it. If the filter becomes torn or cracked, it would have to be replaced.

OIL IS NOT REQUIRED ON THIS TYPE OF FILTER

FLYWHEEL REMOVAL

CAUTION – The fins on the flywheel are made of a hardened plastic material, and can snap off. When positioning your flywheel holder around it to hold it stationary while you are removing the flywheel nut, do so very, very, carefully. Use the same care when installing the flywheel nut back on.

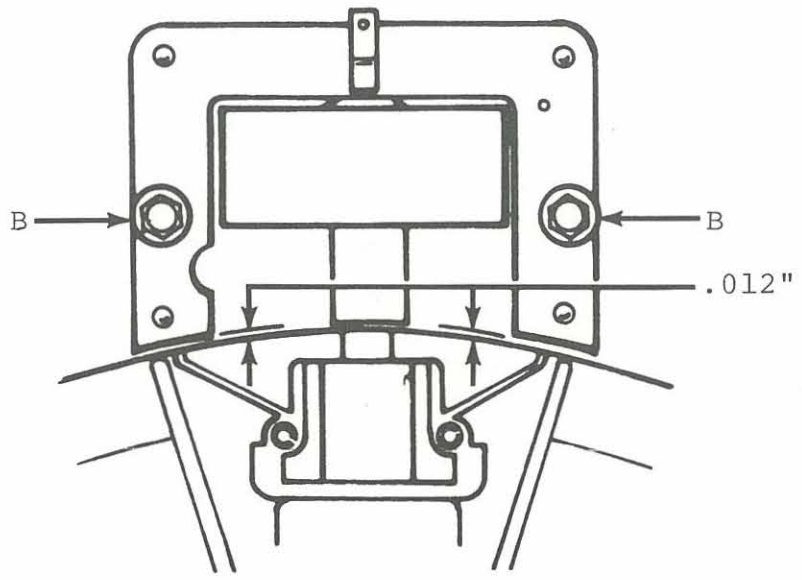
IGNITION

Your engine is equipped with a solid state ignition system. This means that there are no points or condenser. See figure A. This shows the complete solid state ignition system. You will notice that it is located outside of the fly-wheel for easy servicing and repair.

To remove the solid state ignition system, all that is required is to remove the bolts shown at "B".

To reinstall the solid state ignition system, remember to obtain the proper air gap of .012 thousandths. You can use your feeler gauge for this. There is no further timing adjustment on this type of solid state ignition.

Fig. A



REMOVING CRANKCASE COVER

When removing the crankcase cover, do so carefully. This engine is equipped with a mechanical governor, and it is attached to the inside cover plate. Also, you will note that there is a thrust washer right next to the crankshaft gear. Refer to your exploded view drawing, and this is shown at reference number 12. Sometimes, when removing the crankcase cover, this washer will stick to the inside of the crankcase cover, and you will not even be aware of its presence. Note this, as this will be necessary to reinstall back on the crankshaft when you reassemble the crankcase cover back on.

GOVERNOR

This particular engine uses a mechanical governor. This governor uses the principal of centrifugal force to control the speed of the engine. When adjusting this type of governor, the primary objective is to balance the tension spring against the governor action. These variations in adjustments are principly due to linkage design.

BEFORE DISCONNECTING THE GOVERNOR, MAKE A WRITTEN DIAGRAPHM OF HOW THE LINKAGE IS CONNECTED. THIS WILL MAKE REASSEMBLY MUCH EASIER.

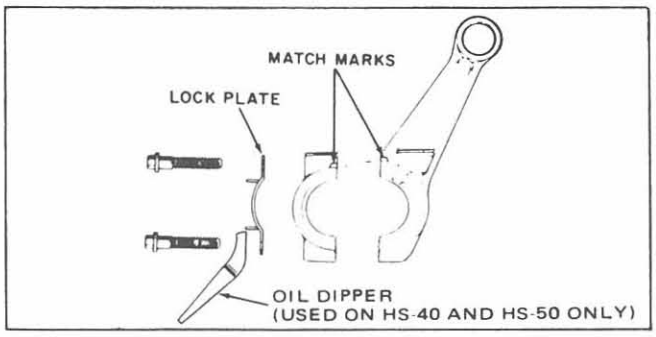
It is not necessary to separate the mechanical governor from the crankcase cover. This would only be necessary if the governor was defective and needed to be replaced.

When reinstalling the governor, the inside governor arm, which is attached to the crankcase block, is to be pointed downward. The governor gear is made of a hardened plastic material, and this has to mesh in with the camshaft gear. When installing the crankcase cover back on, do so carefully.

When the engine is stopped, and the throttle is set on the open or run position, the throttle valve should be in the open position. Improper adjustment of the linkage may cause it only to be part way open.

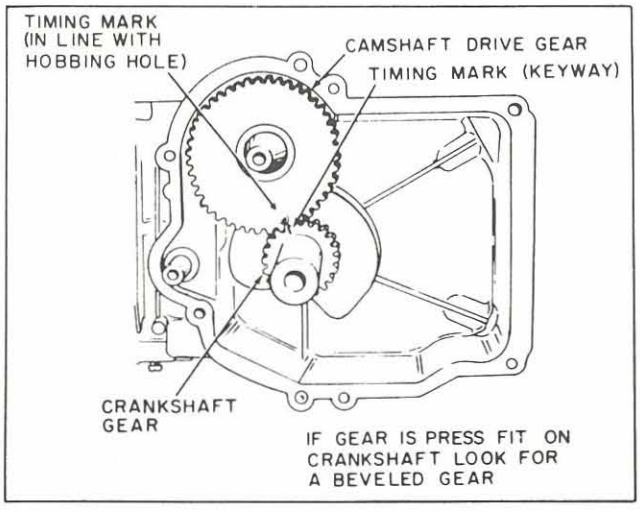
ROD AND ROD CAP ASSEMBLY

When assembling the rod cap and rod to the crankshaft make sure that the match marks are aligned as shown in the drawing below. Note also the position of the oil slinger. This has to be installed as shown to insure proper lubrication.



TIMING MARK ALIGNMENT FOR CRANKSHAFT AND CAMSHAFT

When installing the crankshaft and camshaft back in, they will have to be aligned properly to insure proper valve timing. There is a small mark on the crankshaft gear. Look very carefully and you should have no problem in locating it. Examine now the camshaft gear. You will see that it has a hobbing hole in it. Align the mark on the crankshaft gear so it is centered in the middle of the hobbing hole, as shown below.



EXAMINATION ON LESSON 38
PARTS CATALOG AND TROUBLE SHOOTING

FOLEY-BELSAW INSTITUTE OF
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NAME _____ Student No. _____

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

The questions are multiple choice or True and False. Write your answer in under the ANSWER column on the right hand side of your exam. If the question is a multiple choice, select the letter that answers the question and write that letter in under the ANSWER column. If it is a TRUE or FALSE question, write in T or F under the ANSWER column. The first question has been worked out for you as an example.

ANSWER

1. Give the reference numbers of the following parts shown in Figure 390 of lesson 38.
   - Crankshaft
   - Both valves
   - Rope rewind starter
   - Head gasket
   - Camshaft and gear
   - Piston rings
   - Oil pump
   - Valve lifters
   - Rod
   - Rod cap
   - Float carburetor
   - Mufflers
   - Piston and pin

2. Give all the reference numbers of the starters and fuel tanks shown in Figure 390 of lesson 38.

   Starter _____
   Fuel tanks _____

3. The same basic engine may be equipped with more than one different carburetor. _____
   TRUE
   FALSE

4. The reference numbers in exploded view drawing will refer you to the part number and name. _____
   TRUE
   FALSE

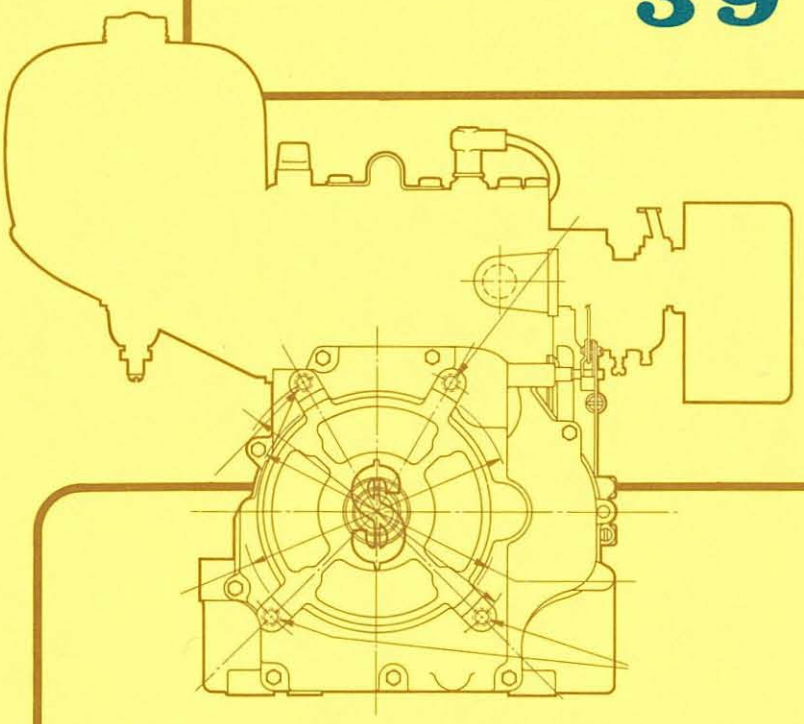
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

39



TURN THIS PAGE

...and let's find out all about --

ENGINE DISASSEMBLY

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INTRODUCTION

In this section you'll begin working with a 4-cycle engine that is typical of the type engines you will be working with as a small engine mechanic. In earlier lessons, we covered the operating principles of both the 2-cycle and 4-cycle engine. The 2-cycle engine is a simple machine having very few moving parts. Actually, the piston assembly and the crankshaft are the only two basic moving parts in a 2-cycle engine. The actual principles of converting chemical energy into mechanical energy and movement are the same. The difference is in the method of performing the necessary functions. The 4-cycle engine is relatively more complicated in that it has many more moving parts. This engine is similar to an automobile, except it has only one cylinder.

In this section of the course we'll completely disassemble a 4-cycle engine, inspect and check all parts, and then reassemble and operate the engine. Before beginning work on your engine you should have a space provided so that you can lay out all the parts in the order of disassembly. Develop good work habits and practice safety. A mechanic with sloppy work habits and a sloppy work area will develop into a sloppy mechanic.

BEFORE OPERATION CHECK

Before beginning work on an engine or starting it always make a complete check for parts that are broken, worn, bent, missing or loose. Always make this before operations check before you start working on the engine. Often you will find defects that you will want to correct before reassembling and make provisions for getting replacement parts. Locate, identify and check all the parts shown in Figure 394. Be sure to know the names and locations of these parts as they relate to your engine. Different engines may have these parts in different locations. Most horizontal shaft engines will have these parts located similar to the ones in Figure 394, however, vertical shaft engines will be different. Their design and basic function will be the same.

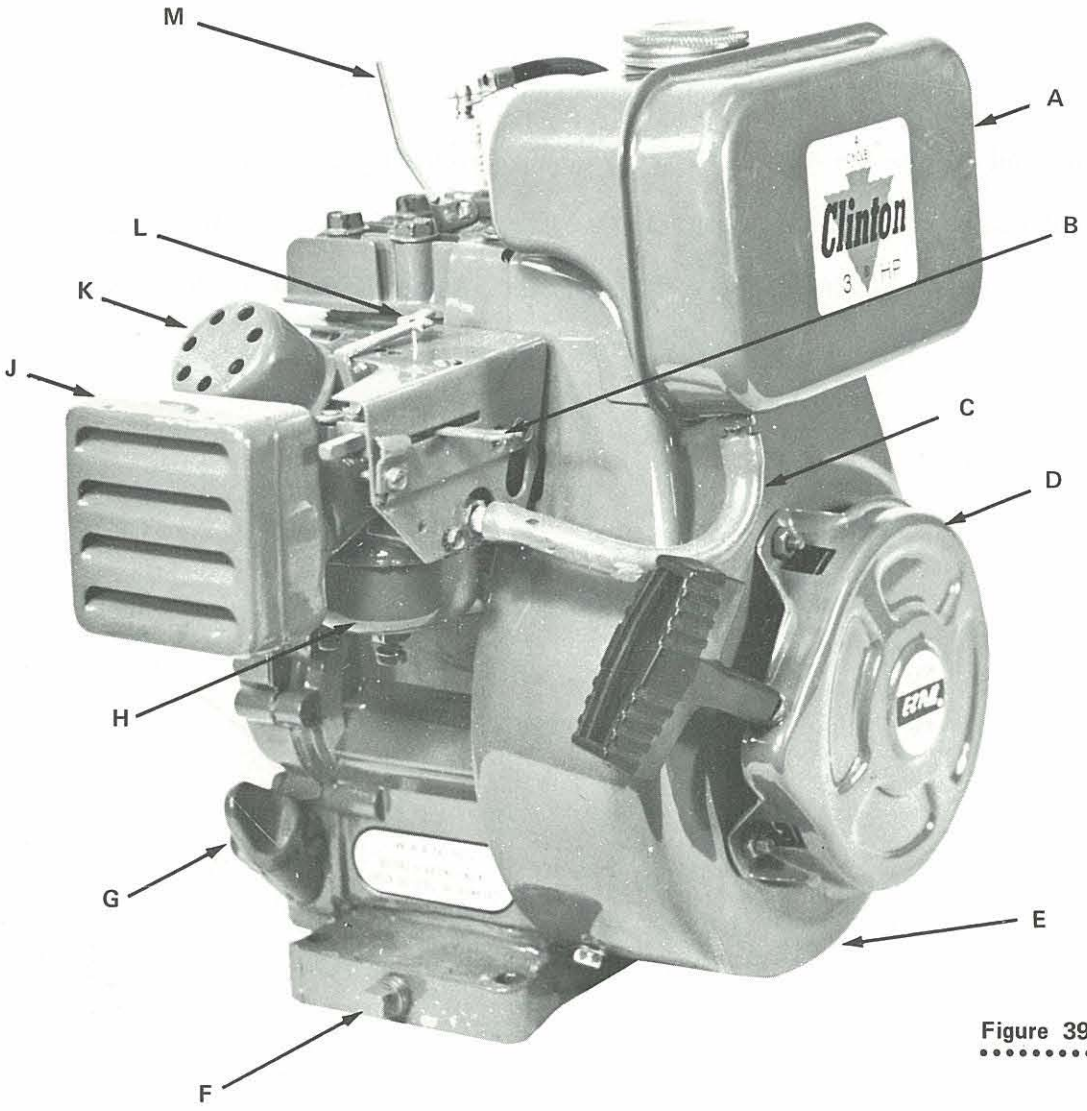


Figure 394

ENGINE SERVICE CHECK

Before starting any engine there are several basic checks that should be made. Figure 395 shows the areas needing service and adjustment needed for your engine. First check the oil level at the filler plug shown at A and fill with recommended oil for 4-cycle engines. Fill the gas tank B, with regular grade gasoline, and check the ground clip shown at C to be sure it is free and not grounding the plug. Set the choke lever, shown at D, all the way toward the engine. This is the full choke position. Move the throttle lever, shown at E, all the way toward the engine. Now the choke is closed and the throttle is full open.

Pull the starter rope a couple times and move the choke back away from the engine to the open position. This fills the combustion chamber with fuel and it should be ready to start. Pull the starter rope again to start the engine.

Allow the engine to run a few minutes to warm up and adjust the high and low speed carburetor jets if necessary. It might be a good idea to review the carburetor adjustment procedures we covered for this type carburetor in an earlier lesson. After you have the engine running properly, stop it and restart without using the choke. With the engine warm it should restart with no choke.

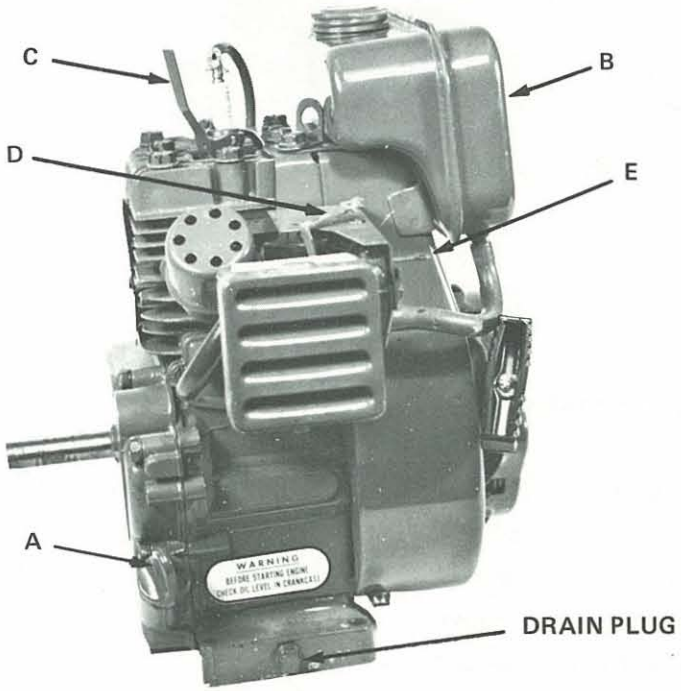


Figure 395

CAUTION

Never run an engine in a closed area without outside ventilation unless you have provisions for venting the exhaust with a hose. Carbon monoxide gas from an engine is very poisonous. Be sure to use regular gasoline and not mixed with oil as for 2-cycle engines.

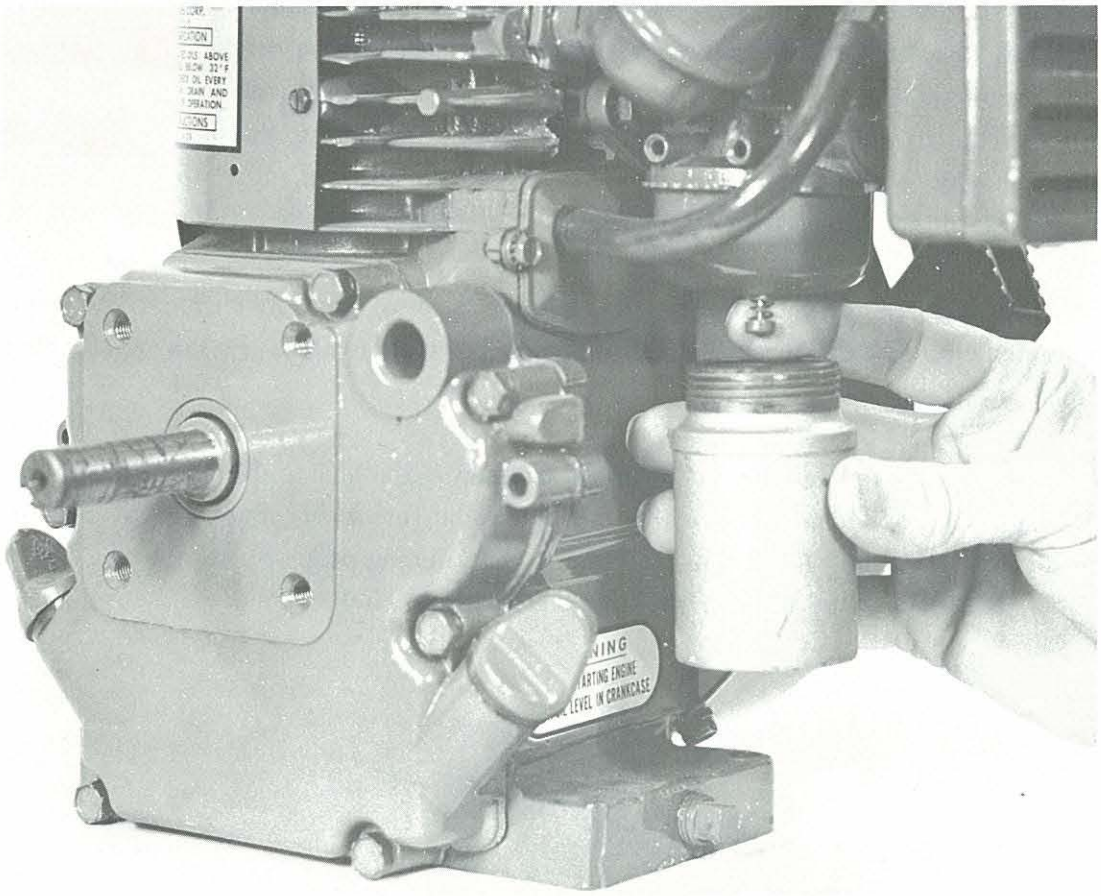


Figure 396

PREPARING ENGINE FOR DISASSEMBLY

The first step in engine disassembly is to remove the high tension wire from the spark plug. This is a safety precaution and should be done any time an engine is being worked on. Next, remove the fuel line from the carburetor and drain the fuel from the tank into a clean can. It will be necessary to remove the gas tank cap to prevent a vacuum from forming in the tank. Drain the fuel from the carburetor bowl, as shown in Figure 396, by pushing up on the bowl drain button located on the bottom of the bowl. This will drain the carburetor float system.

Drain all oil from the crankcase by removing the oil drain plug and tilting the engine slightly. Allow all the oil to drain out and replace the plug.

The engine used in this course will not have oil or fuel so it will be necessary to have these available when you get the engine reassembled and ready for operation. When at all possible, use oil recommended by the manufacturer and listed on the name plate or operating instructions on the engine.

FUEL TANK AND BLOWER HOUSING REMOVAL

Set your engine on a work bench with a large enough top to hold the parts as they are removed or use another bench. The first few times you disassemble an engine it is very important that you keep the parts separated and in groups. This will make reassembly much easier until you are more familiar with all the parts. It is also a good idea to C-clamp the engine to the work-bench.

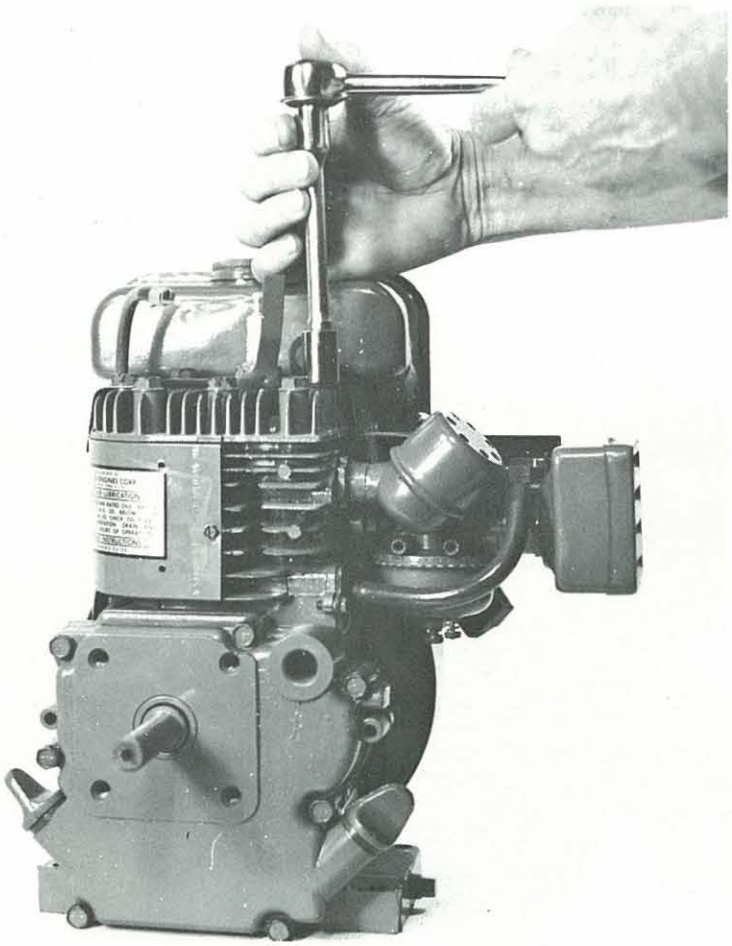


Figure 397

The first step on most small engines is to remove the fuel tank and blower housing. Start by removing the fuel line from the tank. Next, remove the four head bolts shown in Figure 397. After the head bolts, remove the two bolts at the lower part of the blower housing. The entire blower housing and fuel tank can now be removed. The starter assembly will also come off with the blower housing. Do not remove the starter at this time.

CARBURETOR CONTROL PLATE REMOVAL

Remove the fuel line from the carburetor. There is another flexible hose just behind the air cleaner that goes to the valve tappet cover that should be removed. Next, remove the two screws shown at A and B in Figure 398. These hold the mounting bracket to the body of the carburetor. The screw shown at C is used to hold the remote control throttle cable going to the equipment. The throttle control lever, shown at D, has a spring attached to it that goes to the throttle control. Remove this spring from the throttle and leave it attached to the control plate. *Be sure to remember which hole this spring was removed from.* Set the control plate and spring aside so that it can be kept with the rest of the carburetor. Replace the two screws in the carburetor housing.

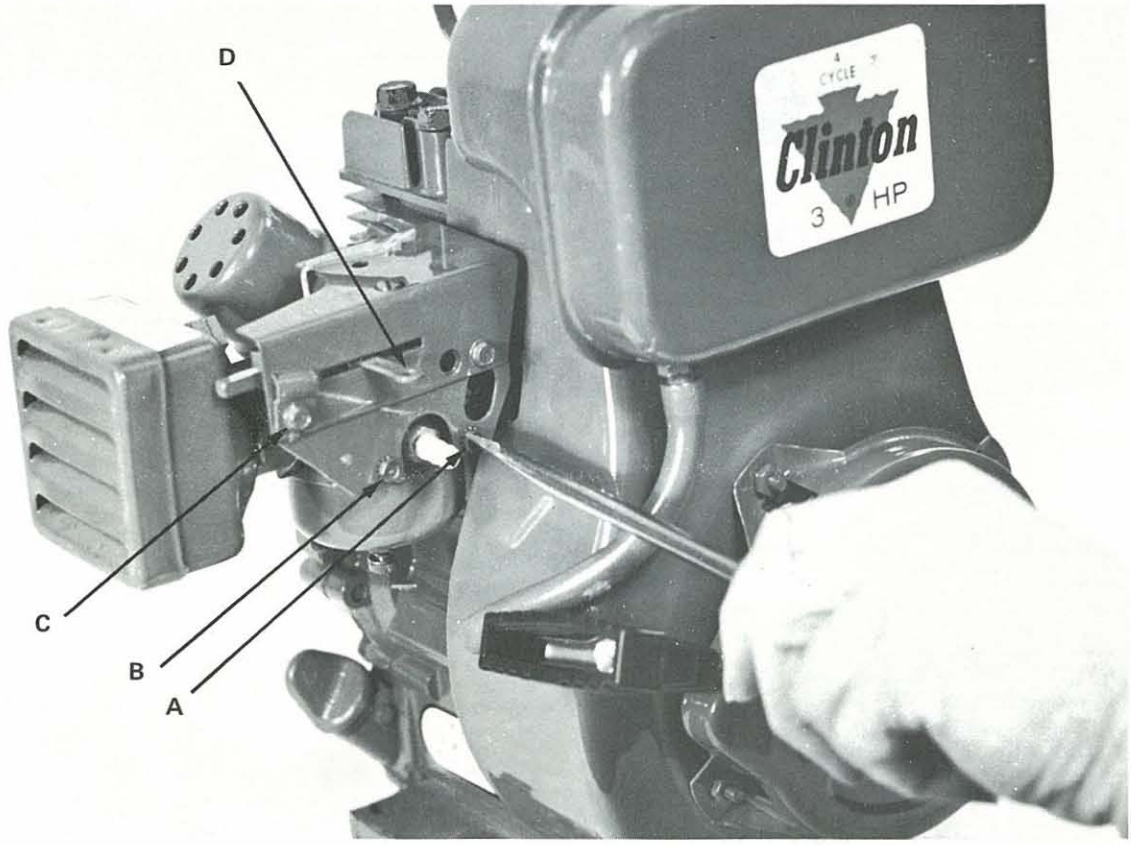


Figure 398

CARBURETOR REMOVAL

After the blower housing is removed the engine should look like Figure 399. Remove the governor control arm shown at A. Before removing take note of the shape of the arm and how it is fitted to both the throttle lever and the governor air vane. Slip the air vane off the pivot post before attempting to remove the control arm. After the control arm and air vane is removed, attach the arm back on the air vane and set aside with the other blower housing parts.

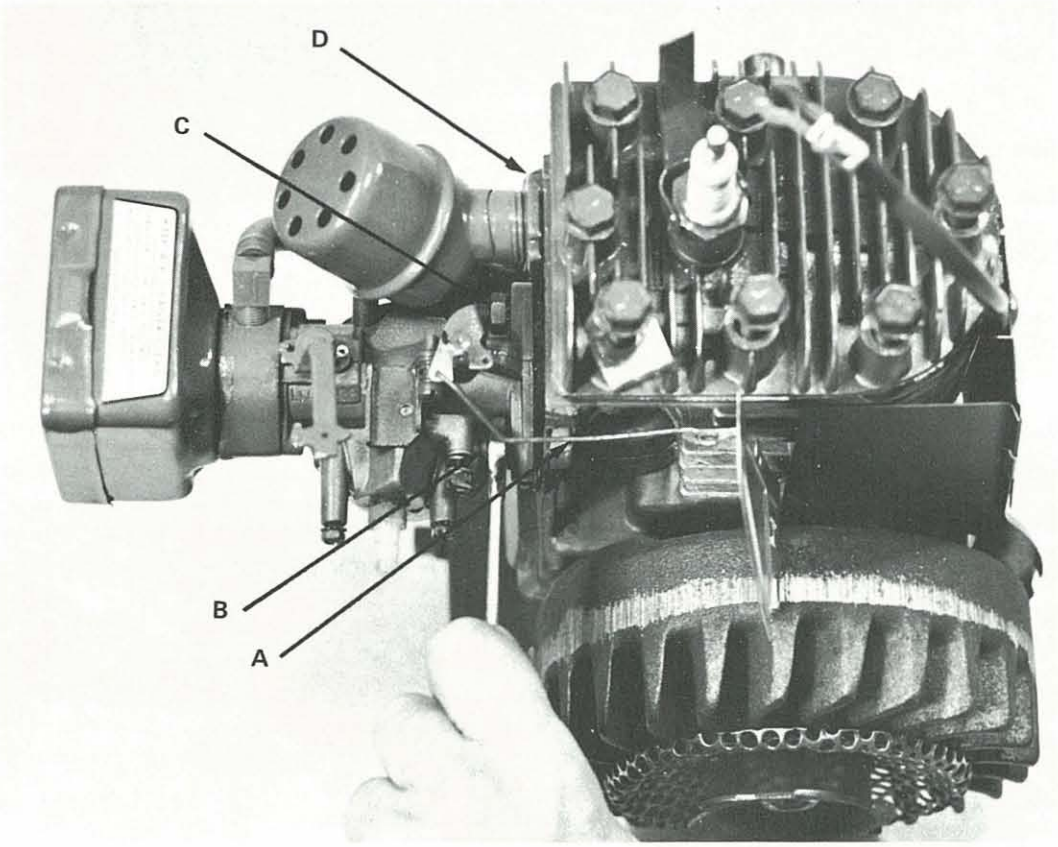


Figure 399

At this time it would be a good idea to put all the parts you have removed so far in the blower housing. Next, remove the two nuts shown at B and C and slip the carburetor off the bolt studs. Be careful of the gasket. It may come off with the carburetor or it may stick to the engine block. Install the gasket back on the engine block along with the two nuts and set the carburetor aside for now. Loosen the lock nut shown at D and unscrew the muffler.

FLYWHEEL NUT REMOVAL

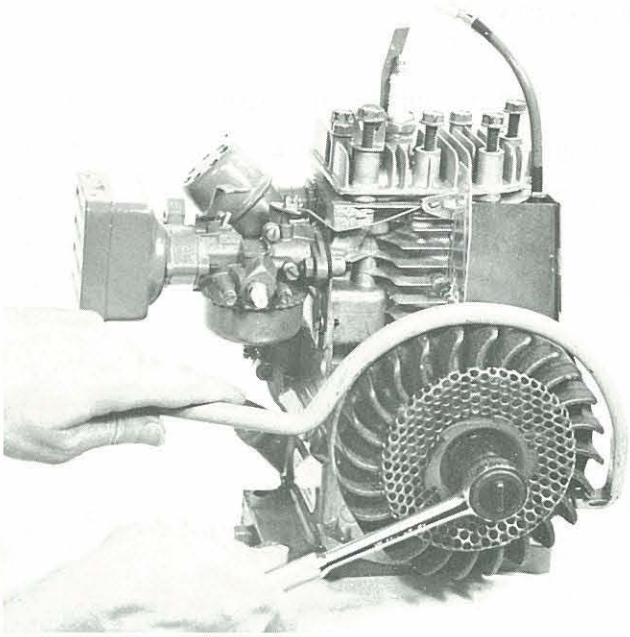


Figure 400

Remove the flywheel nut as shown in Figure 400. Often the flywheel nut can be removed by striking the wrench a sharp blow to loosen the nut. If a flywheel removal tool is used, position it as shown and turn the wrench counter-clockwise to loosen. Remove the nut, lock washer, starter cup and screen guard. Notice there are two ears on the inside of the starter cup. These engage the fins of the flywheel for turning. Place these pieces together and keep with the blower housing parts.

FLYWHEEL REMOVAL

To remove the flywheel from the crankshaft it will be necessary to use an impact nut, as shown in Figure 401. Thread the impact nut all the way on the shaft, just finger tight. Then, loosen the nut about one full turn and strike a sharp blow with a hammer as shown at A. This will jar the flywheel loose from the crankshaft. Never use the flywheel nut to jar the flywheel loose. There is danger of damaging the threads or breaking off the end of the crankshaft. When you feel the flywheel loose, remove the nut and flywheel. Take notice of how the key is fitted to the shaft. Remove the key and set aside with the flywheel. Remove the small part of the air shroud that is still attached to the engine. This part is held in place with two small screws. Replace the screws in the block.

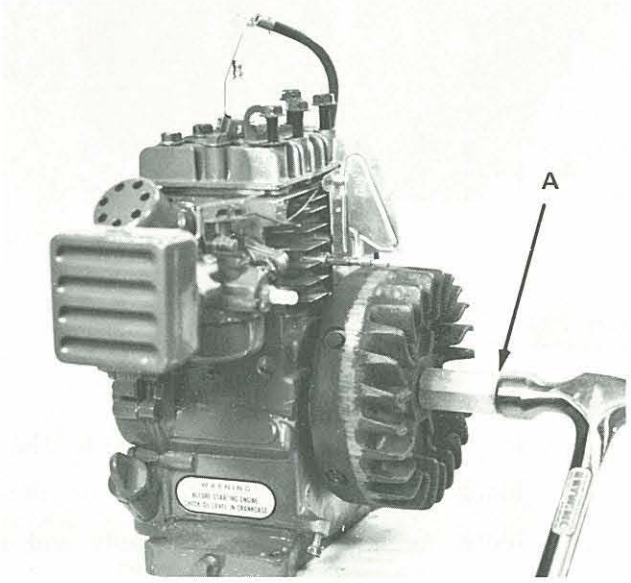


Figure 401

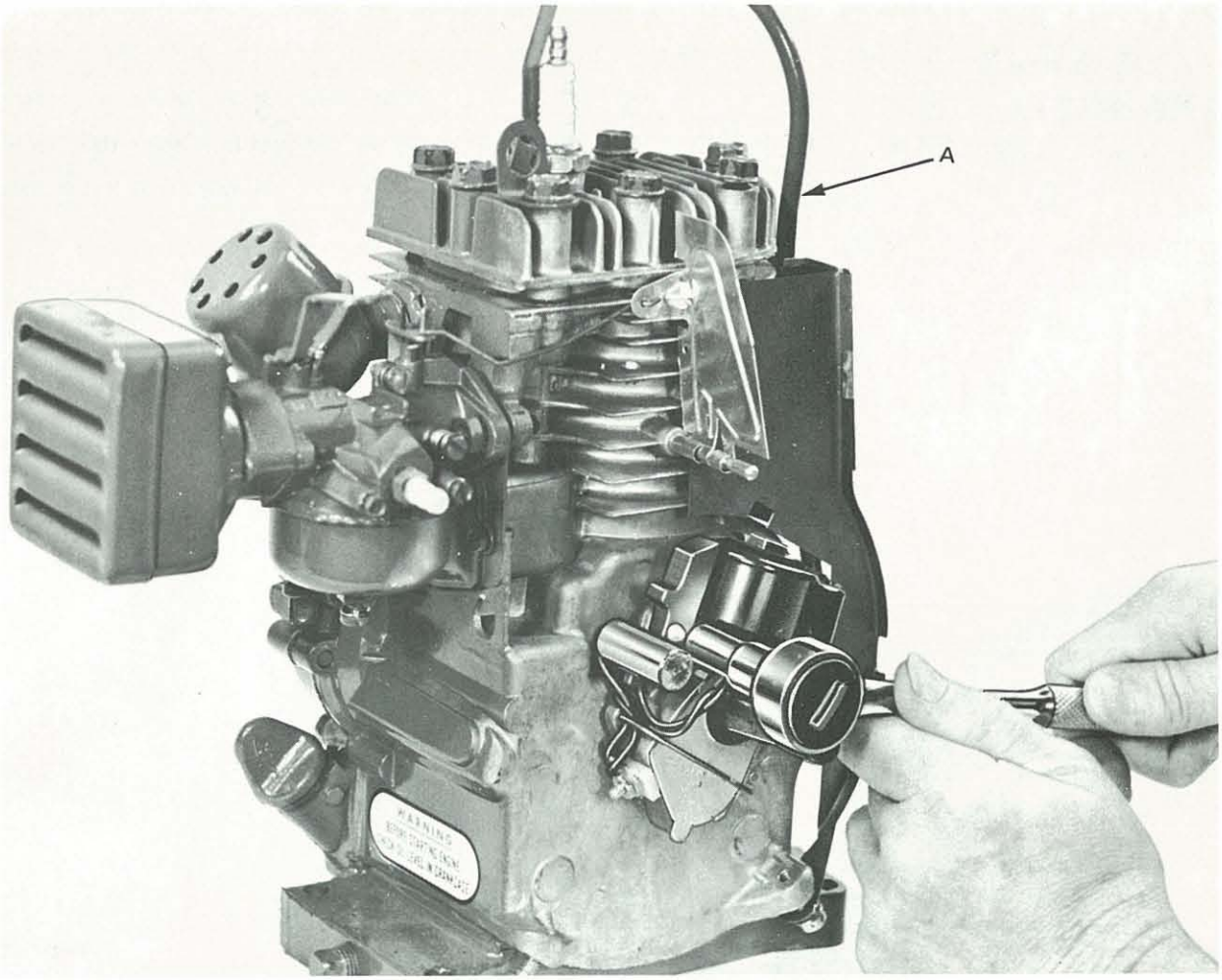


Figure 402

IGNITION REMOVAL

Before beginning to remove the magneto coil and stator plate, inspect it carefully for any timing or location marks. Some engines have an adjustable magneto assembly that must be marked or checked before removing. Others do not and are positioned with pre-set holes.

The magneto assembly, shown in Figure 402, is held in place with two bolts. First remove the high tension wire shown at A. Pull it straight out of the coil and remove the wire from the magneto assembly. Next, remove the two bolts holding the magneto to the engine and the entire magneto assembly will come off. Be sure to remove the cam from the crankshaft and keep with the magneto parts.

HEAD AND SPARK PLUG REMOVAL

Remove the spark plug with a deep socket or spark plug wrench. Some engines have spark plugs set too deep in the cooling fins to permit removal with a regular wrench. Always use a spark plug socket when possible. Next remove all the head bolts and lift off the head and gaskets as shown in Figure 403. Sometimes the gasket will come off with the head or it may stick to the cylinder block. Sometimes it will come apart and stick to both the head and the block.

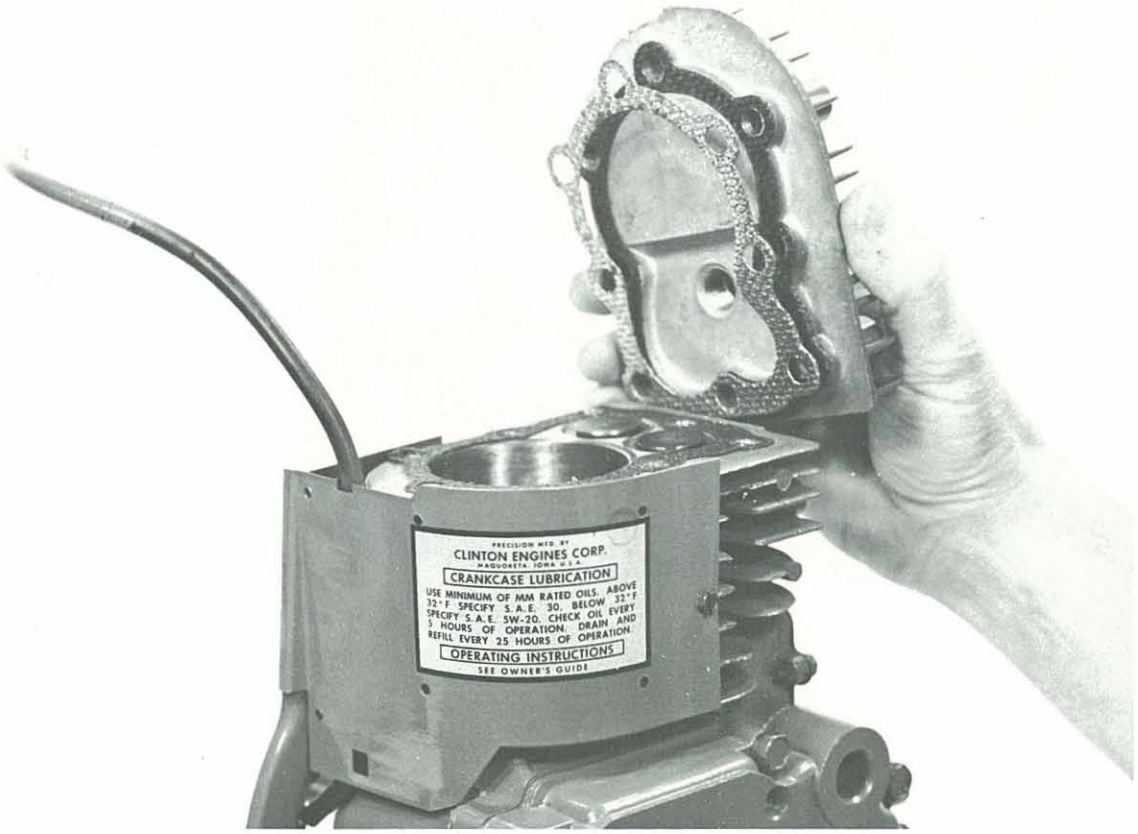

CLINTON ENGINES CORP.
CRANKCASE LUBRICATION
USE MINIMUM OF MM RATED OILS. ABOVE 32° F SPECIFY S. A. E. 30. BELOW 32° F SPECIFY S. A. E. 5W-20. CHECK OIL EVERY 5 HOURS OF OPERATION. DRAIN AND REFILL EVERY 25 HOURS OF OPERATION.
OPERATING INSTRUCTIONS
SEE OWNER'S GUIDE

Figure 403

As soon as you have the head removed, turn the crankshaft to close both valves and bring the cylinder to top dead center. If part of the gasket remains on the block, clean it and the head. Since this gasket has been under compression, only a short time, it generally is not necessary to replace it with a new one. Pay particular attention to the head bolts as you remove them. Some of them may be longer than others. Make a note and replace them the same way they are removed.

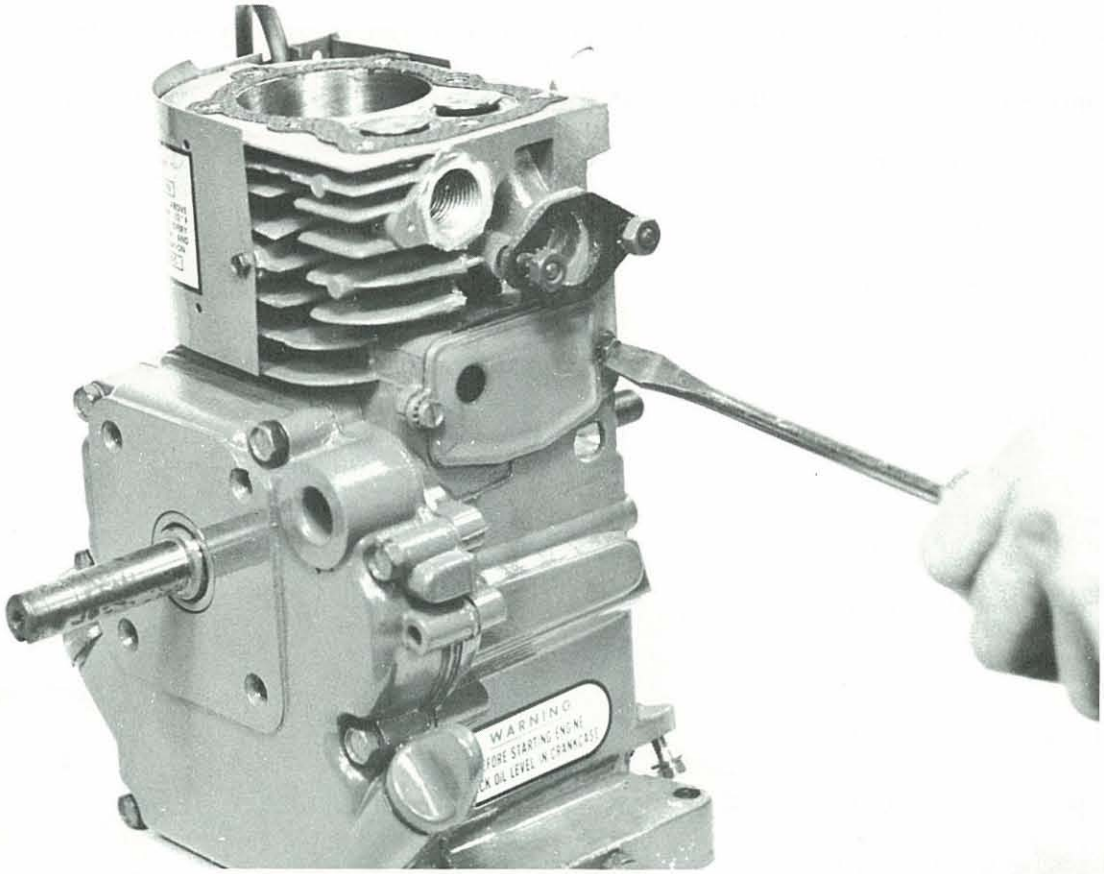


Figure 404

VALVE COVER REMOVAL

Remove the valve cover plate as shown in Figure 404. Next, remove the cover and breather assembly. There are two gaskets with this assembly. One is between the cover plate and the breather and the other is between the assembly and the engine housing. Be careful in removing the breather assembly so as not to damage either gasket. Earlier we covered the function of the breather assembly. This is a valve that helps your crankcase breathe. Put the two screws that were holding the breather assembly on your work bench with the other parts.

VALVE REMOVAL

Before beginning to remove the valves it would be a good idea to review the section covered earlier on valve assembly construction. First, turn the crankshaft until both valves are completely closed. This will relieve most of the spring tension. Using a valve lifter, as shown in Figure 406, slip the forked prong of the tool into the last coil of the spring and position the screw at the top directly over the valve head. Turn the screw until the valve spring is compressed. Remove the valve keeper with a pair of needle nose pliers or move it around with a screwdriver and it will slip off the valve stem. Do not reach in this area with your fingers. After the valve keeper is released from the stem, the valve can be lifted out the top.

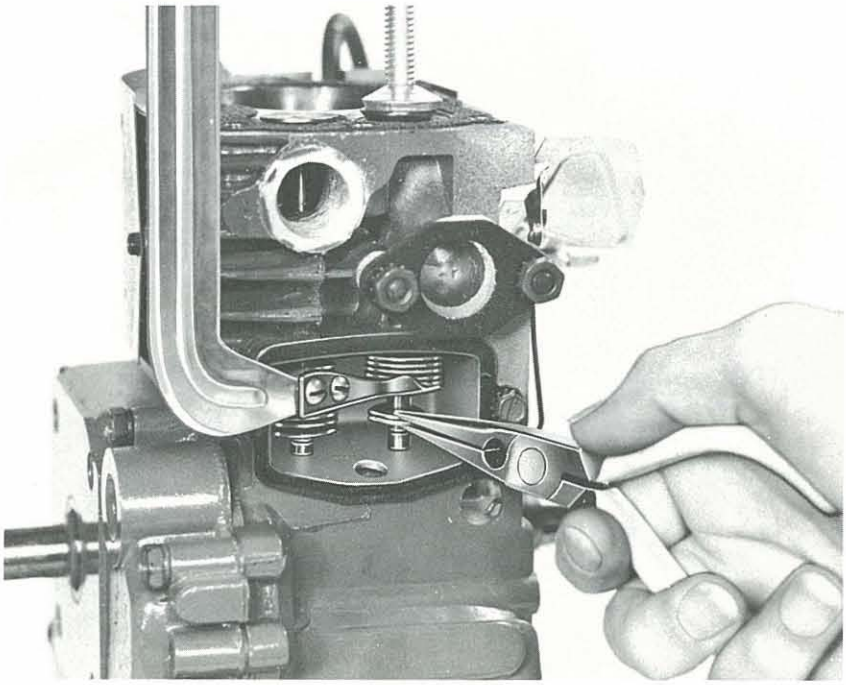


Figure 406

Remove the valve, valve spring and keeper and set them together.

Next, remove the other valve. Do not mix the valve springs. They should be replaced in the same position as they were removed. If you are not sure you can identify the valves it may be a good idea to mark the top of both the intake and the exhaust valve on the top. You can locate the position of the exhaust and intake valves by their location in relationship to the exhaust and carburetor intake.

CRANKCASE COVER REMOVAL

To remove the crankcase cover it will be best to turn the engine down as the camshaft will sometimes come out and allow the valve lifters to fall down into the crankcase. Remove all the bolts holding the cover as shown in Figure 407. The cover is located on the housing with two locating pins in the area shown at A and B. Tap in this area lightly with something soft and the cover should slip loose. The oil retainer is located in the housing as shown at C. Be careful when removing the cover not to damage the oil seal on the crankshaft. In case of an oil leak, this seal can be replaced from the outside without removing the cover.

Slide the cover off the locating pins just enough to see if the gasket is going to stick to the cover or the engine block. Be careful not to damage this gasket. Place the bolts you took out in the cover plate so they will be available when you reinstall the cover.

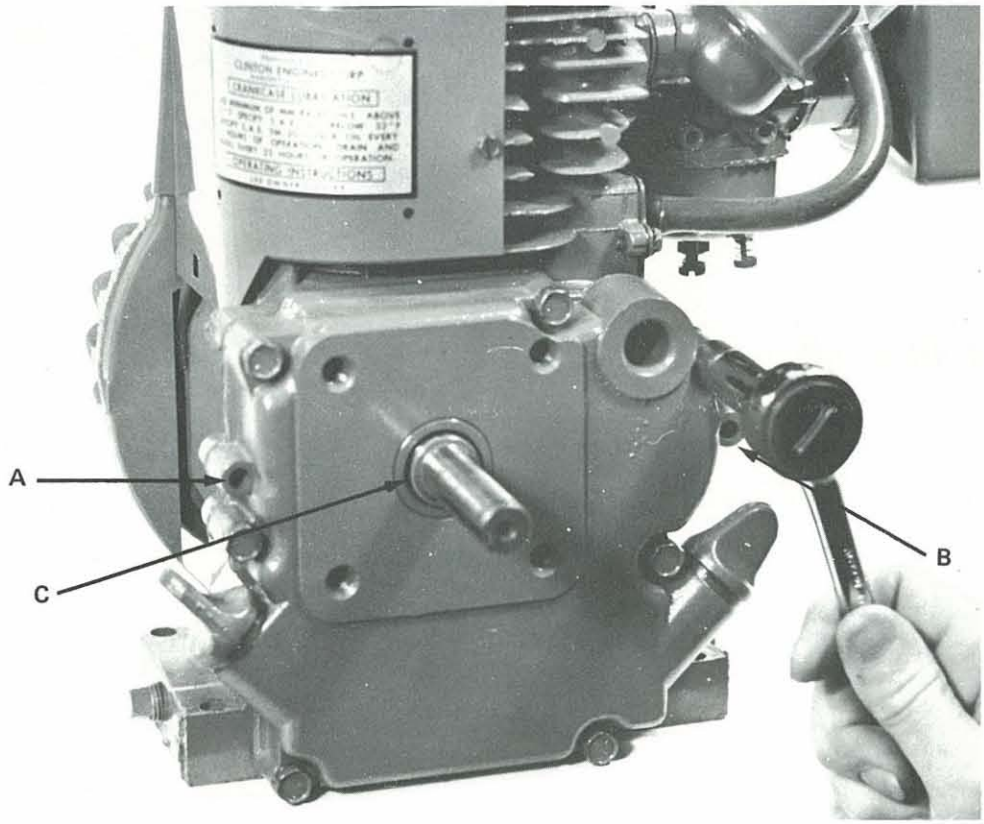


Figure 407

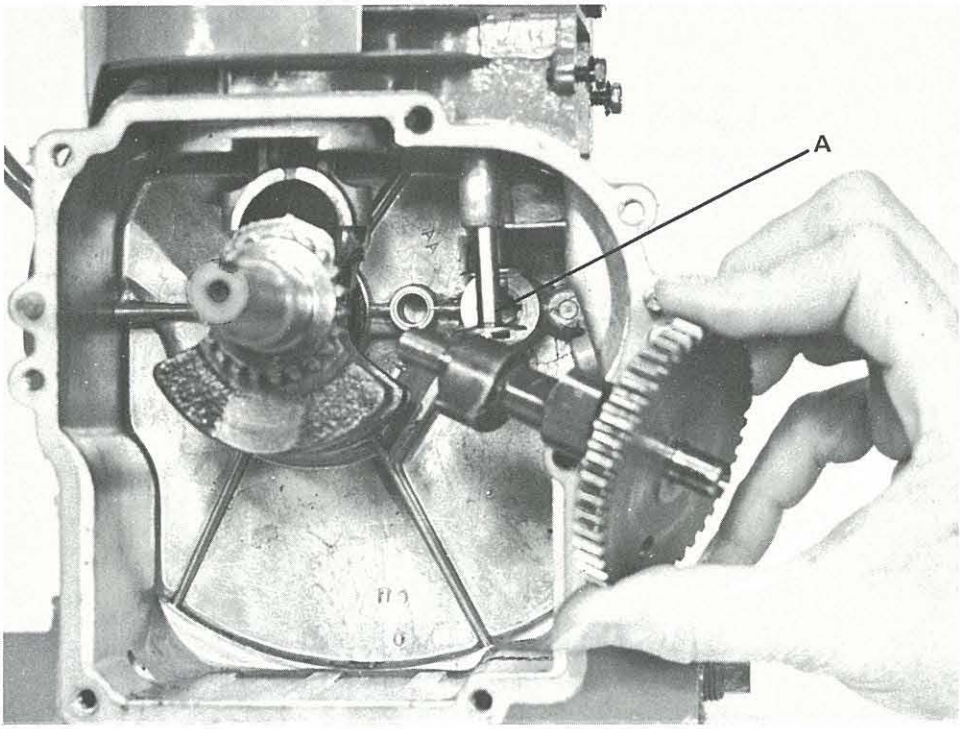


Figure 408

CAMSHAFT REMOVAL

With the engine tilted, slowly remove the camshaft as shown in Figure 408. Be careful so that the valve lifters, shown at A, do not fall out as you will want to replace them in the same holes. Put the camshaft with the cover plate. Remove and mark the valve lifters and lay them with the valves, springs and keepers. If you have both valve assemblies laid out in the order of their removal, it will be easier when reinstalling them.

PISTON AND CRANKSHAFT REMOVAL

Tilt the engine on its side by letting it rest on the threaded end of the crankshaft. Be careful not to damage the crankshaft threads. To remove the rod cap, first release the lock tabs shown at A in Figure 409. Use a screwdriver to wedge the lock tab away from the bolt head, then straighten with a pair of pliers. Bend up far enough so you can get a socket or open end wrench on the bolt head.

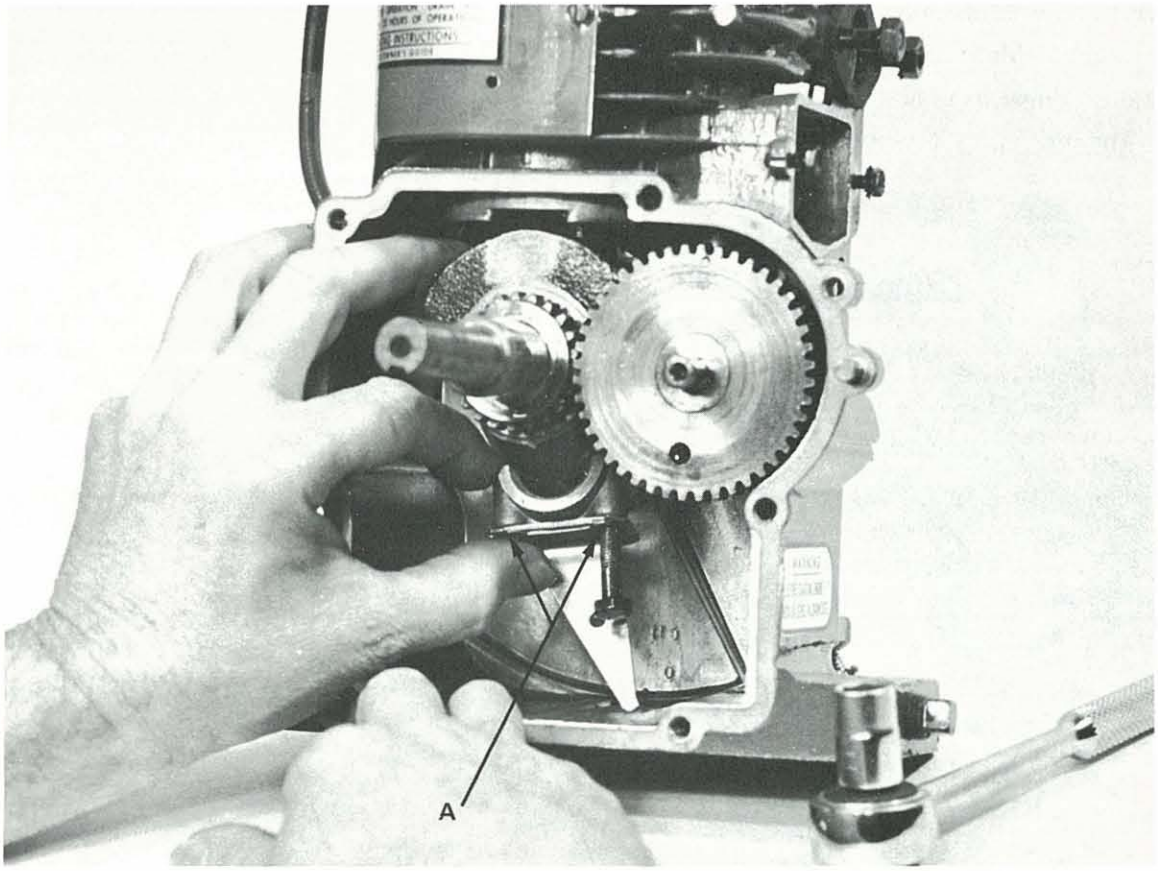


Figure 409

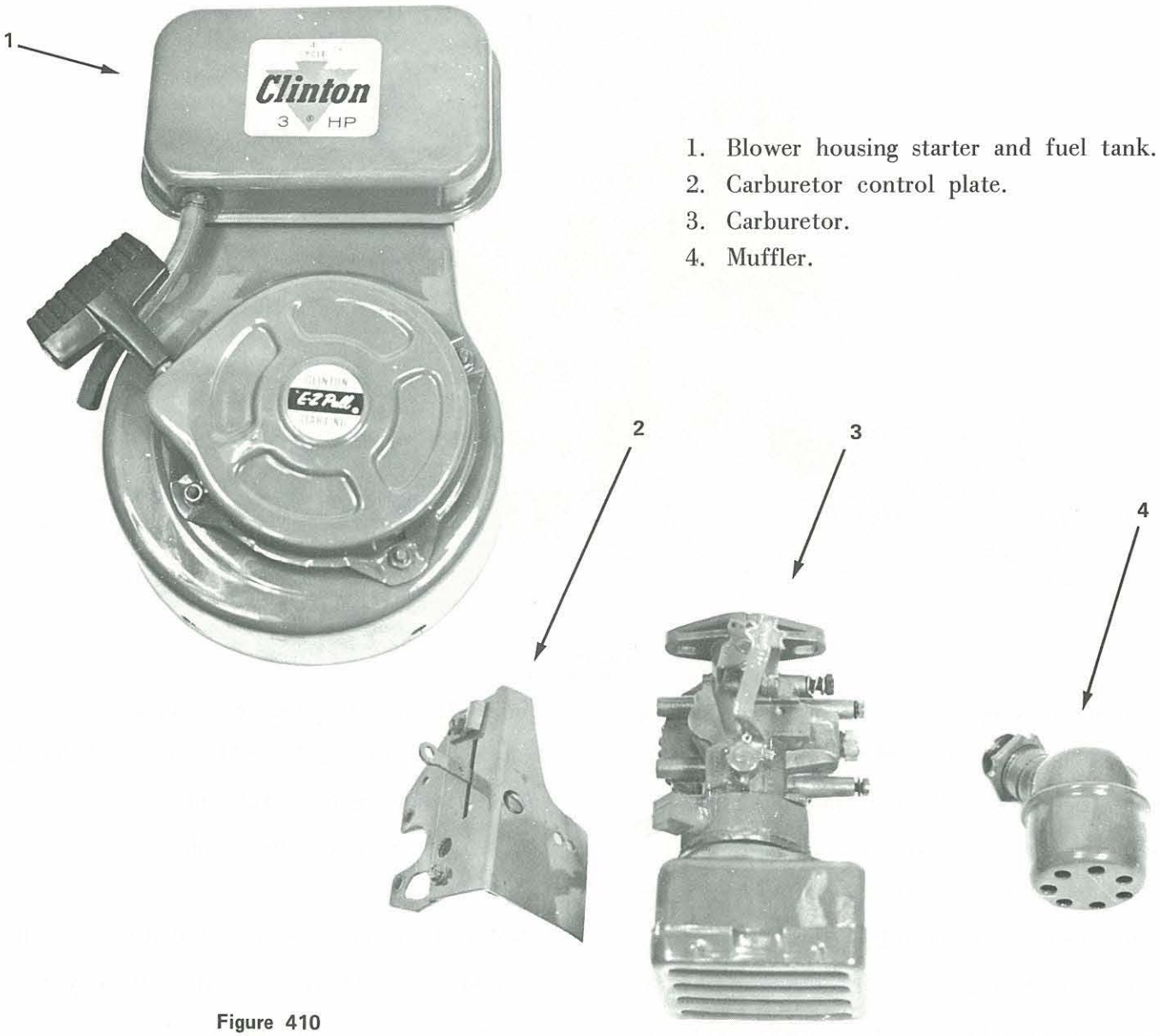
Before removing make a note of the position of the oil slinger. Notice it is pointed to the right. It is necessary that this part be replaced the same way in order to get proper oil distribution in the crankcase. The lock tabs have two ears on each side. To lock the bolt it is necessary to use only one tab on each bolt. When you remove the rod cap, first look for the match marks and determine which side they were positioned on. Generally these match marks will be on the side facing you. If they are not marked, make an identification mark so you can reassemble the same way.

Next, lift the piston straight out the top of the cylinder and pull out the crankshaft. Lay these parts out in order on your workbench.

DISASSEMBLY LAYOUT

Service mechanics often develop a very sloppy way of laying out the parts after they have been disassembled. Much time can be saved by developing a system and getting into the habit of following it. When you begin reassembling your engine you will find there are some parts that must go on before others. It is just as easy to develop the habit of laying them out in the order of their removal as it is to just scatter them on the work bench.

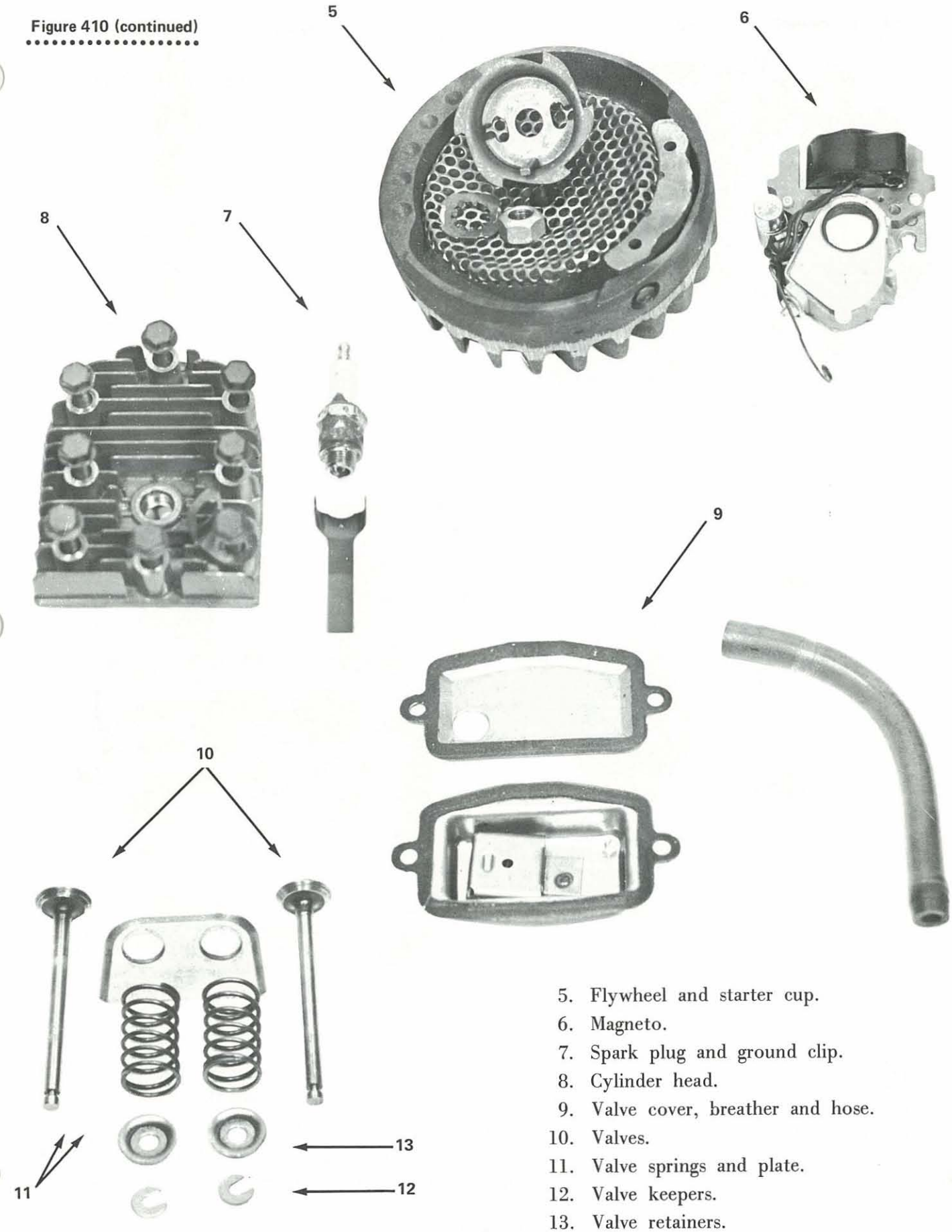
There are two methods you can use to keep nuts, bolts and screws from becoming mixed or lost. You can put them back in their original location or keep them with the parts they are used with. Figure 410, below and continued on pages 17 and 18, shows one of the easiest ways to lay out the parts after they are removed. This is in the order they were removed and will make it much easier when reassembling.



1. Blower housing starter and fuel tank.
2. Carburetor control plate.
3. Carburetor.
4. Muffler.

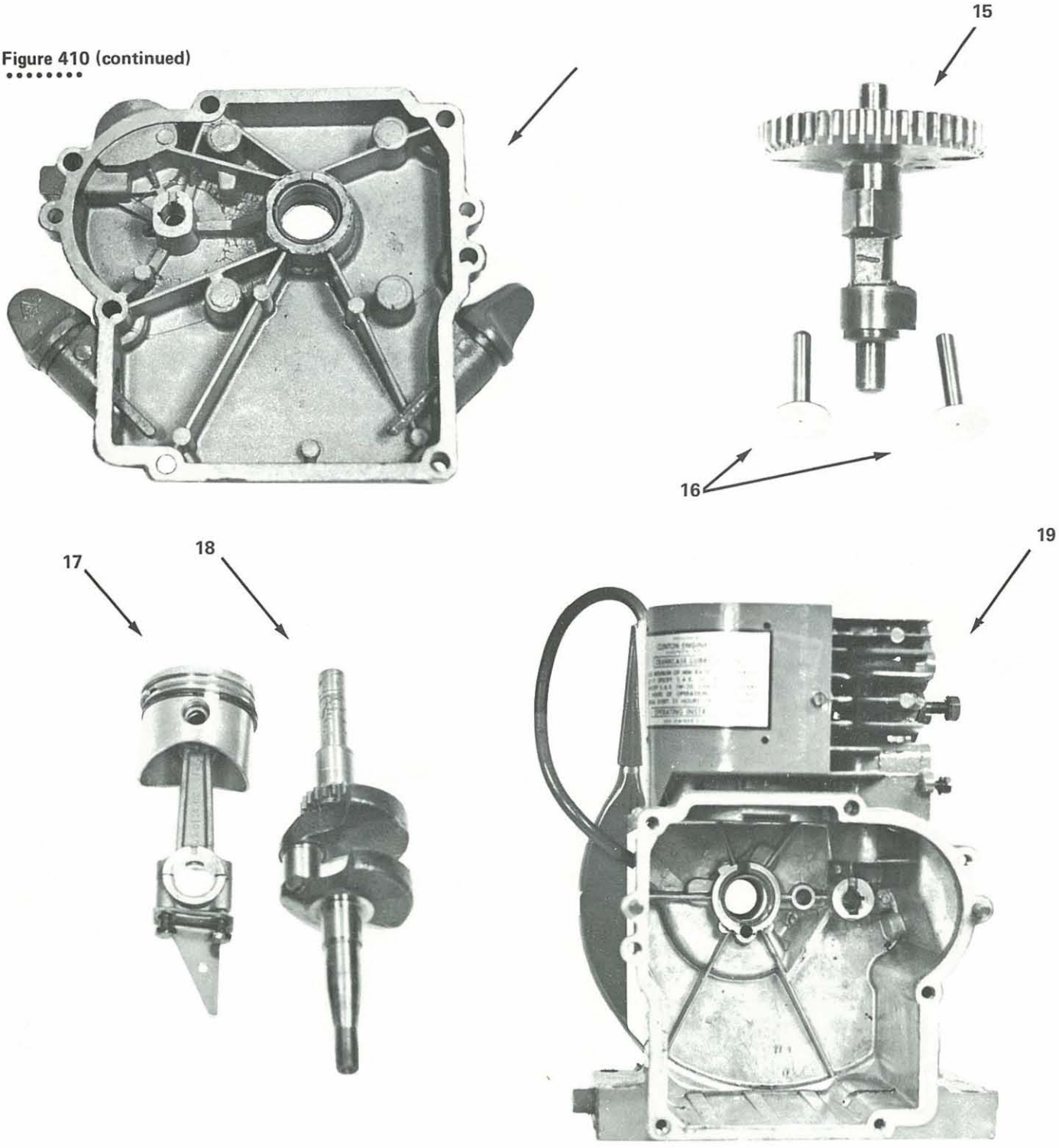
Figure 410

Figure 410 (continued)



5. Flywheel and starter cup.
6. Magneto.
7. Spark plug and ground clip.
8. Cylinder head.
9. Valve cover, breather and hose.
10. Valves.
11. Valve springs and plate.
12. Valve keepers.
13. Valve retainers.

Figure 410 (continued)



14. Cover plate.
15. Camshaft.
16. Valve lifters.
17. Piston and rod assembly
18. Crankshaft.
19. Engine block.

At this point your engine should be completely disassembled except for the carburetor, magneto and starter which you will disassemble and put back together before reassembly. Do not remove the rings from the piston. Very often they will break on removal and it is necessary to install a new set.

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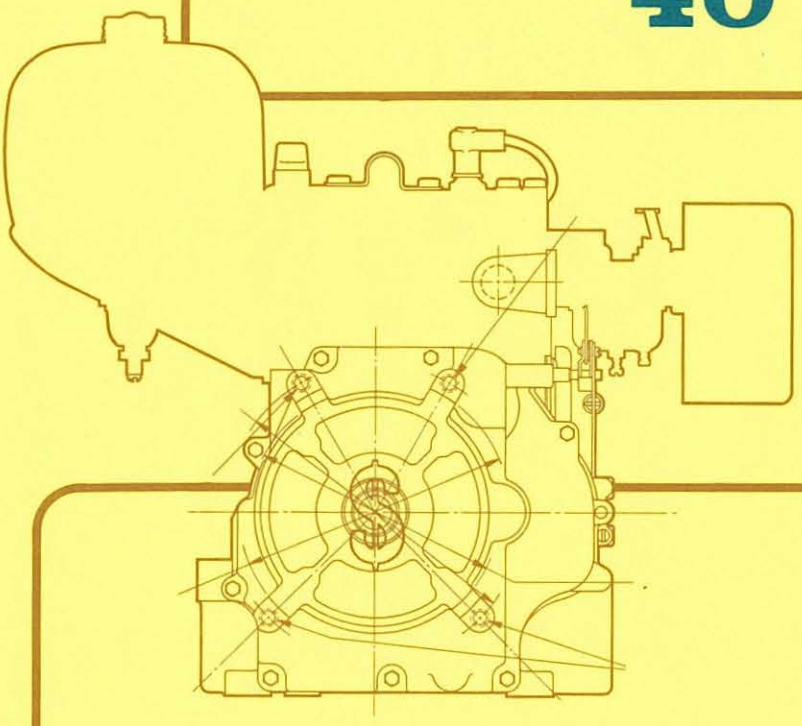

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ENGINE ASSEMBLY

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CRANKSHAFT INSTALLATION

Before beginning to reassemble your engine, examine all the parts closely to become familiar with their appearance and names. Carefully insert the threaded end of the crankshaft into the engine housing as shown in Figure 411. The main crankshaft bearing and the oil seal were not removed from the engine housing. Be careful when installing the crankshaft not to damage the oil seal. Line up the crankshaft with the bearing and push it straight in until it bottoms against the engine block. Next, turn the crankshaft until the crank is at the bottom of the housing as shown at A. The crankshaft counter weights should be up, towards the top of the cylinder.

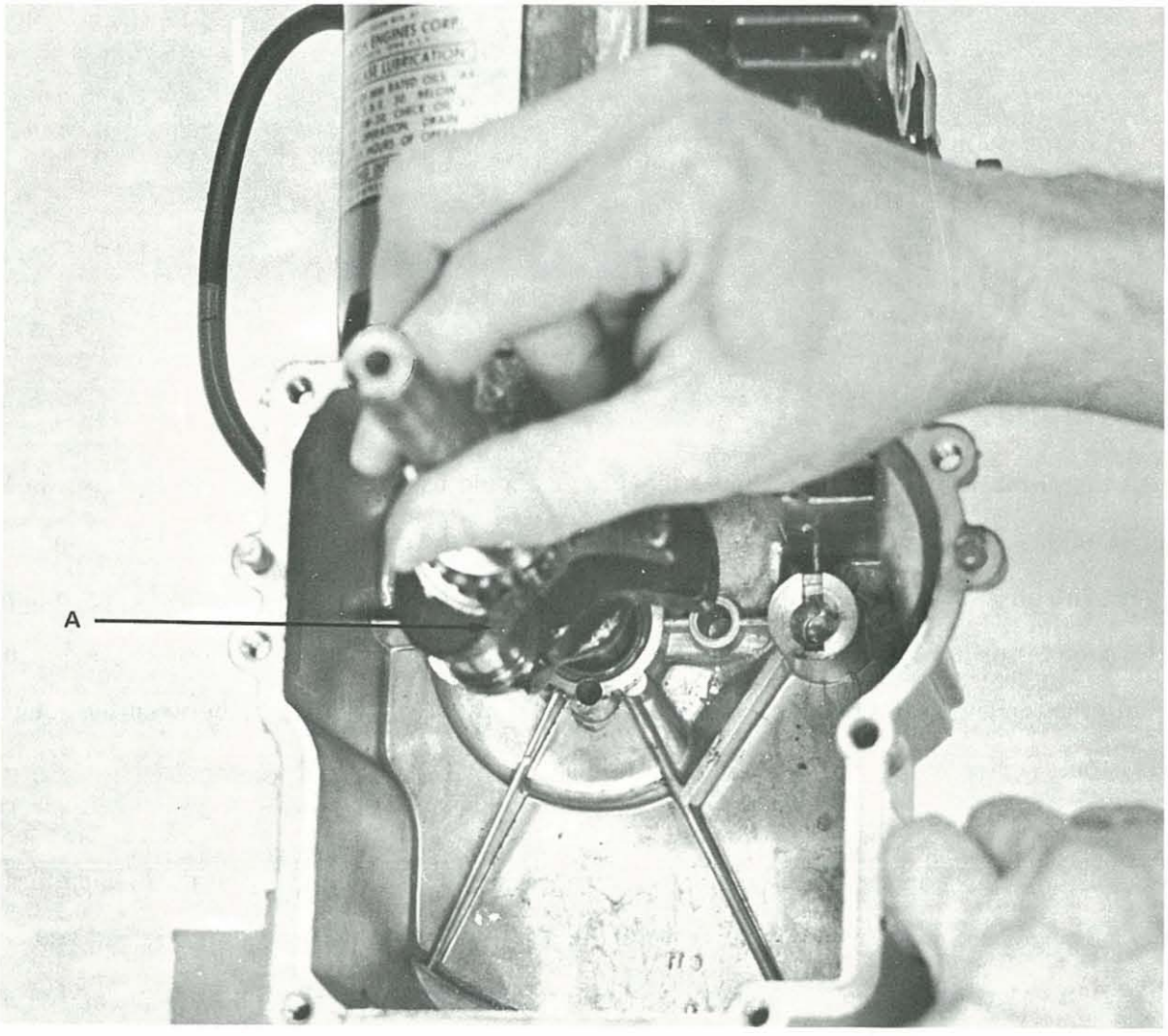

Figure 411

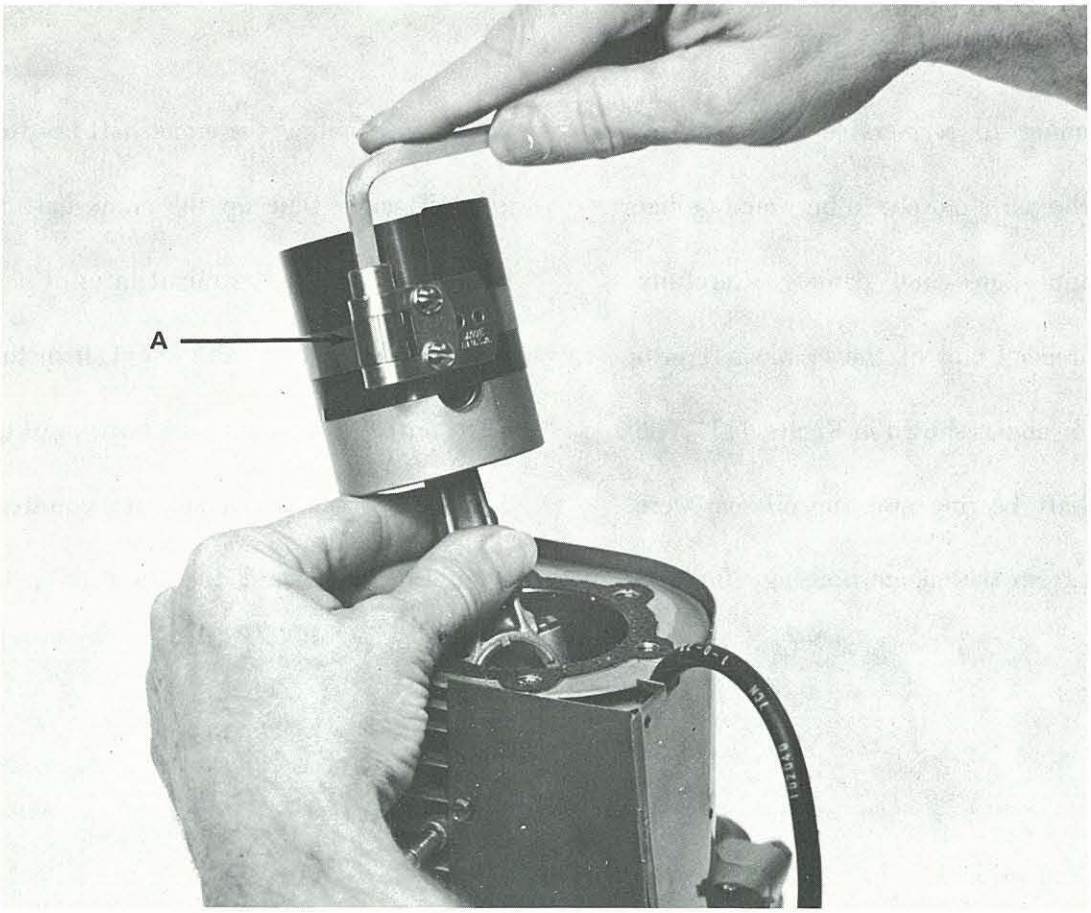

Figure 412

PISTON AND ROD ASSEMBLY

To install the piston and rod in the cylinder block, you should use a ring compressor as shown in Figure 412. First, oil the inside of the cylinder and the rings. Position the ring compressor on the piston as shown and begin tightening. Be sure it is lined up even around the piston and that all rings are being compressed. After the compressor has the rings seated in the grooves of the piston, tighten the lock screws shown at A. Check both the top and bottom of the compressor to be sure that there is no space between the compressor and the piston.

Insert the piston and rod in the cylinder until the ring compressor rests on the top of the cylinder head. Be sure the rod alignment mark is facing you. Push the piston all the way down until the rod seats on the crankshaft. In order for the rod to fit, the crankshaft must be seated against the bearing plate. Loosen the lock screws and release the tension on the ring compressor.

ROD CAP ASSEMBLY

The rod cap, oil slinger and lock tab should be installed at the same time as shown in Figure 413. First, be sure the oil slinger has the straight edge as shown at A, to your right as you are looking at it and the rod cap mark matches the mark on the rod. Put a small amount of oil on the crankshaft. Be sure the rod cap fits snug on the crankshaft and tighten the two bolts with a small wrench. These bolts should be tightened to a torque between 100 and 125-inch pounds.

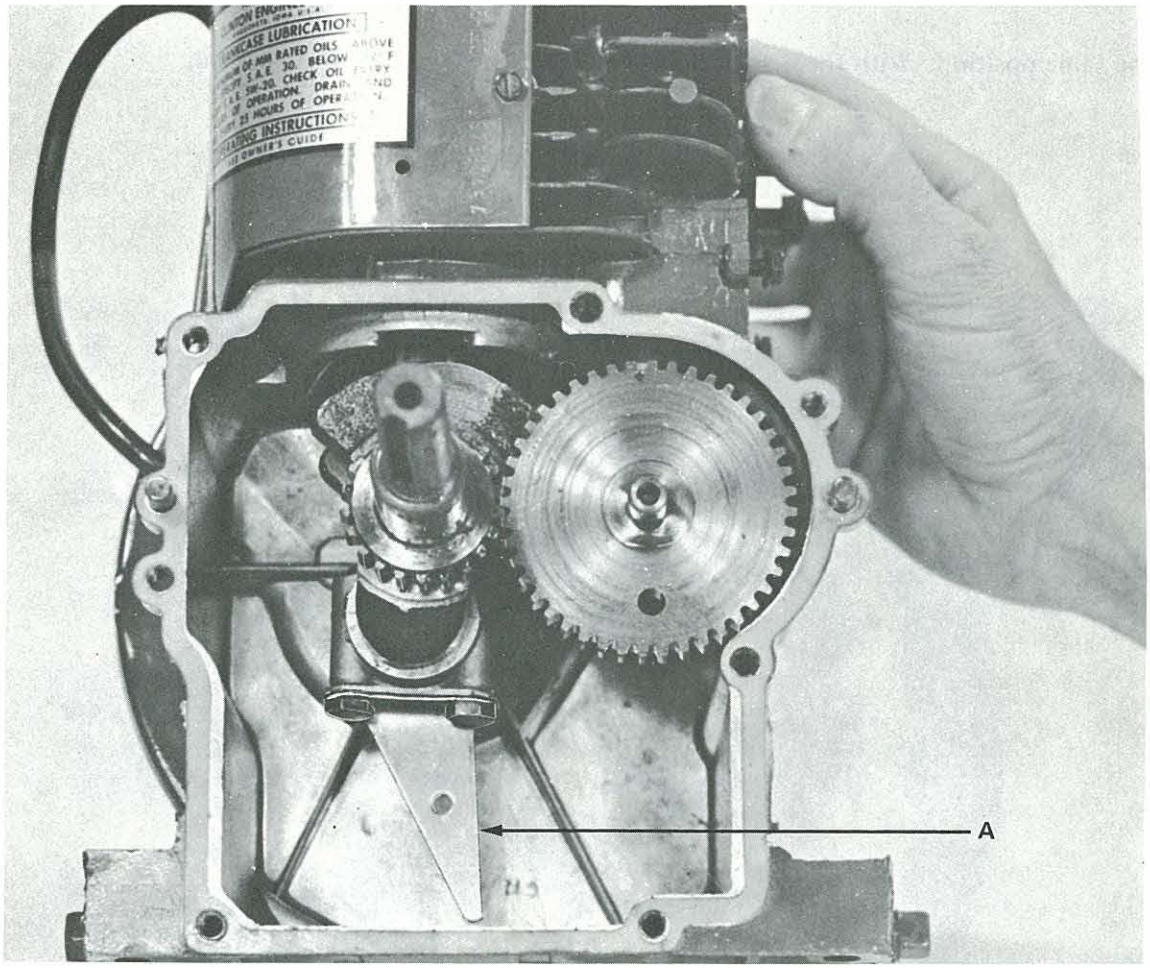

Figure 413

VALVE LIFTER ASSEMBLY

Install both valve lifters as shown in Figure 414. The lifter for the intake valve is shown at A, and the exhaust valve lifter is shown at B. If at all possible, install these exactly as they were removed. After an engine has been operated for some time, all the parts begin to wear; some more than others even though they may be identical parts. When new, these lifters are supposed to be made to the same tolerances but, after some engine use, one of them could show more wear than the other. It is always a good idea to replace them in the same position. With the engine on its side, push both lifters all the way in.

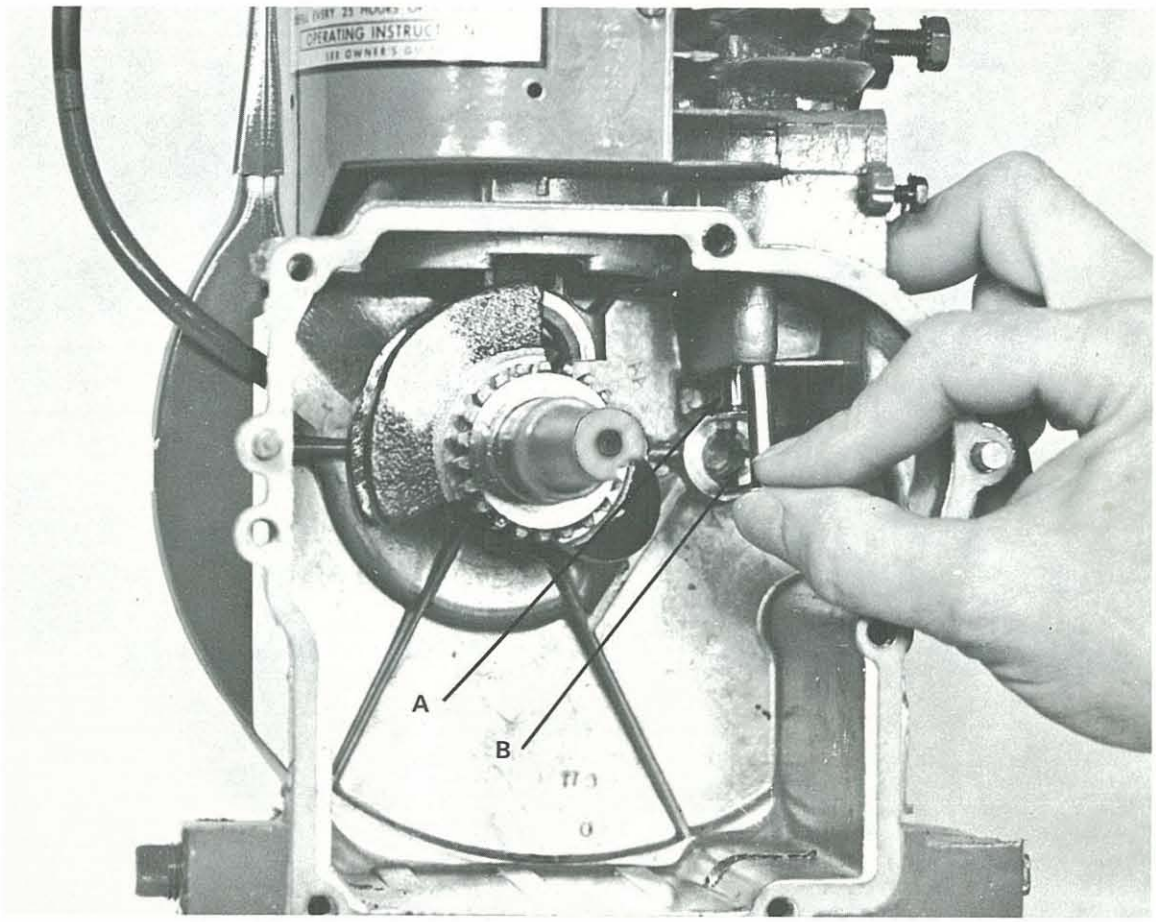

Figure 414

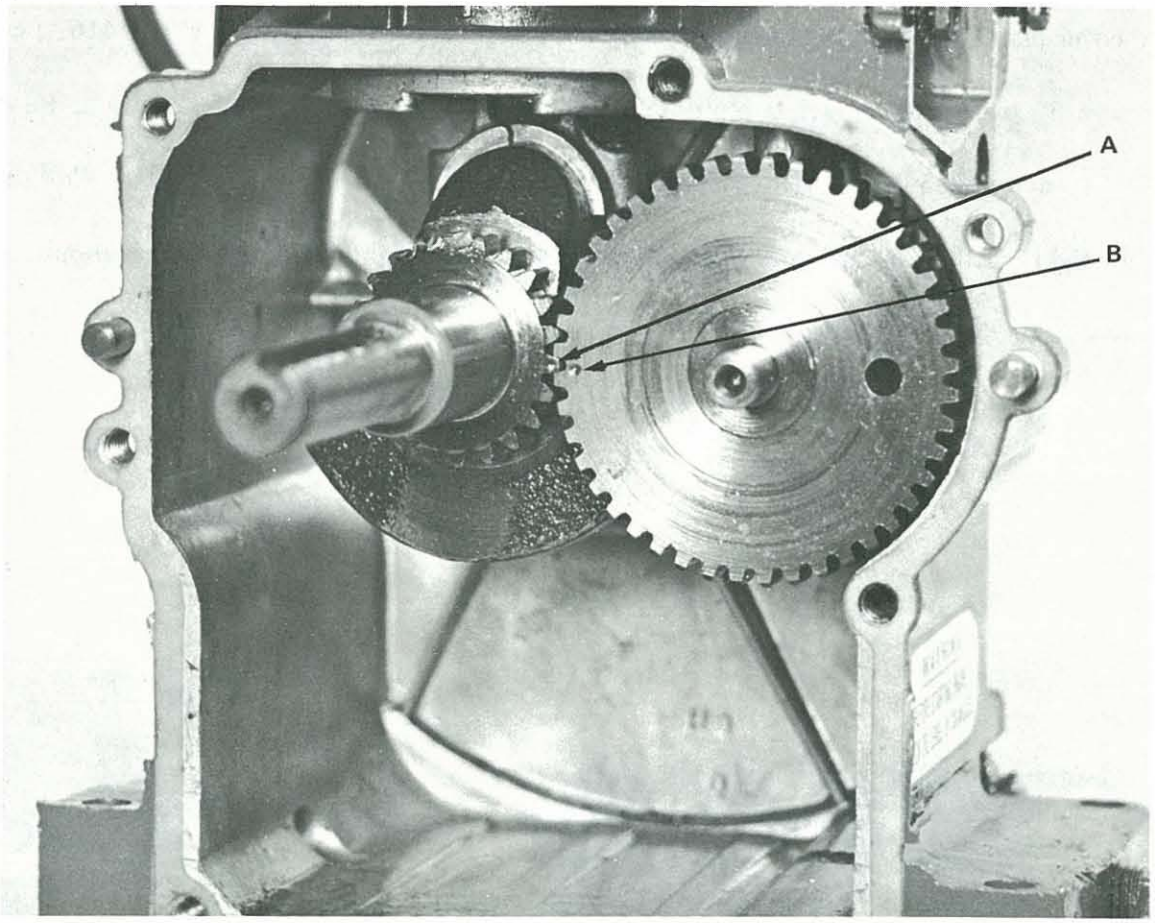

Figure 415

CAMSHAFT ASSEMBLY

Locate the timing mark on the crankshaft gear and turn it to the position shown in Figure 415. The piston will be at top dead center when the timing mark on the gear is in this position. Turn the engine on its side and raise both valve lifters. Install the timing gear so the mark shown at B lines up with the one on the crankshaft gear. Both valve lifters will be riding on the low part of the crankshaft cams. When these gears are installed, as shown, the valves will be in time with the piston. Do not change the crankshaft from this position. With the lifters riding on the low part of the cam, this is the position you will use to check the valve tappet clearance.

COVER PLATE ASSEMBLY

Install the cover plate gasket on the engine housing and the cover plate as shown in Figure 416. Be careful not to damage the oil seal. There are two pins that will locate the cover in the proper position. Be sure the cover is all the way on the pins and flat against the engine housing before installing the bolts. Pull each bolt up snug, not tight, all the way around. Then, go around again and tighten all bolts. These should be tightened to about 75 to 85 inch pounds.

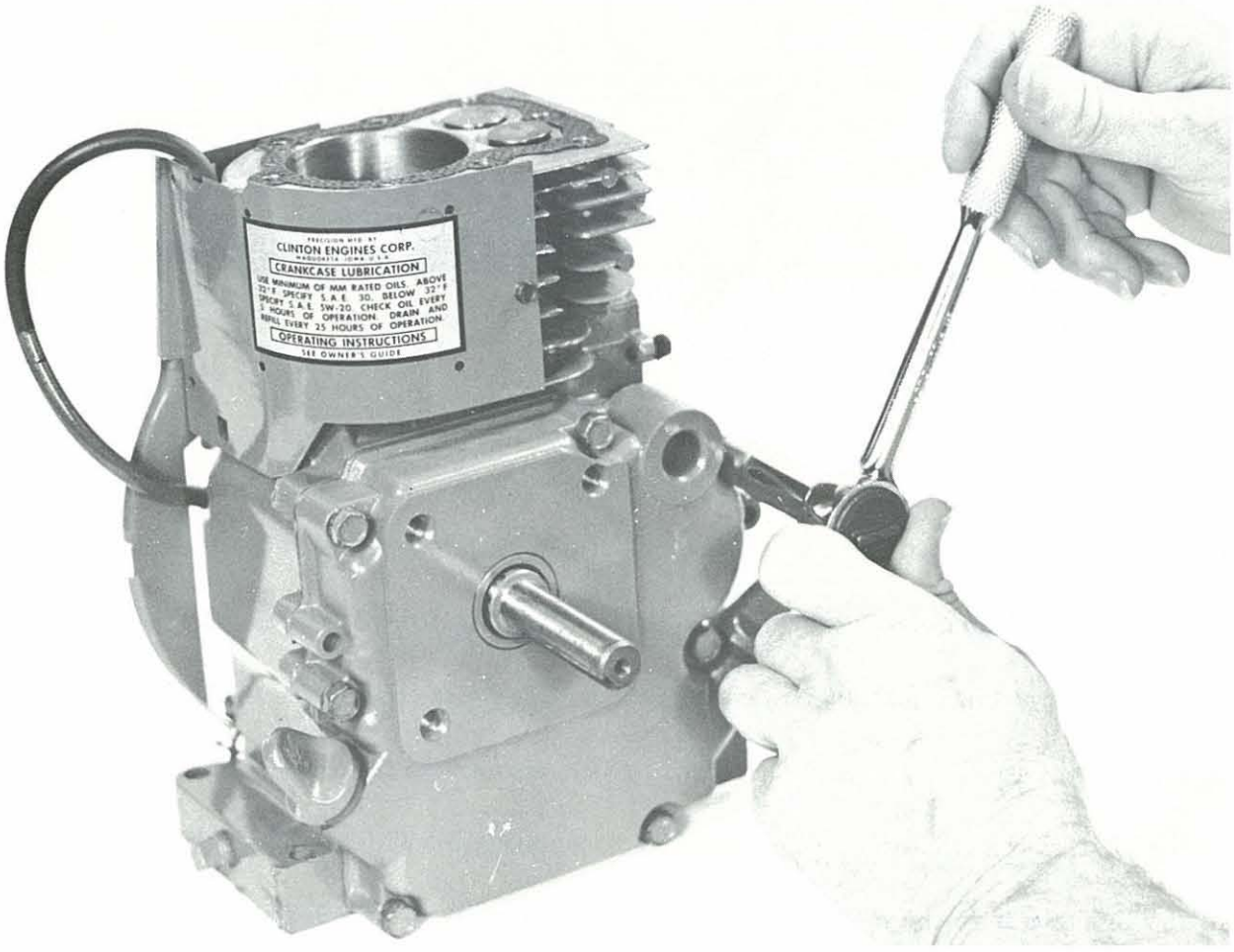

Figure 416

INSTALLING VALVES

If the crankshaft has not been turned it should still be in the position so both valve lifters are riding on the low part of the cam and both valves should be closed. Check the valve-tappet clearance with a feeler gauge as shown in Figure 417. The intake valve should be between .007 and .009-inch and the exhaust valve between .009 and .011-inch. Your engine could be just a little tight or loose on this check, but this is the desired setting range. Push down on the top of the valve when making this check. You should be able to feel just a very slight drag on the feeler gauge blade.

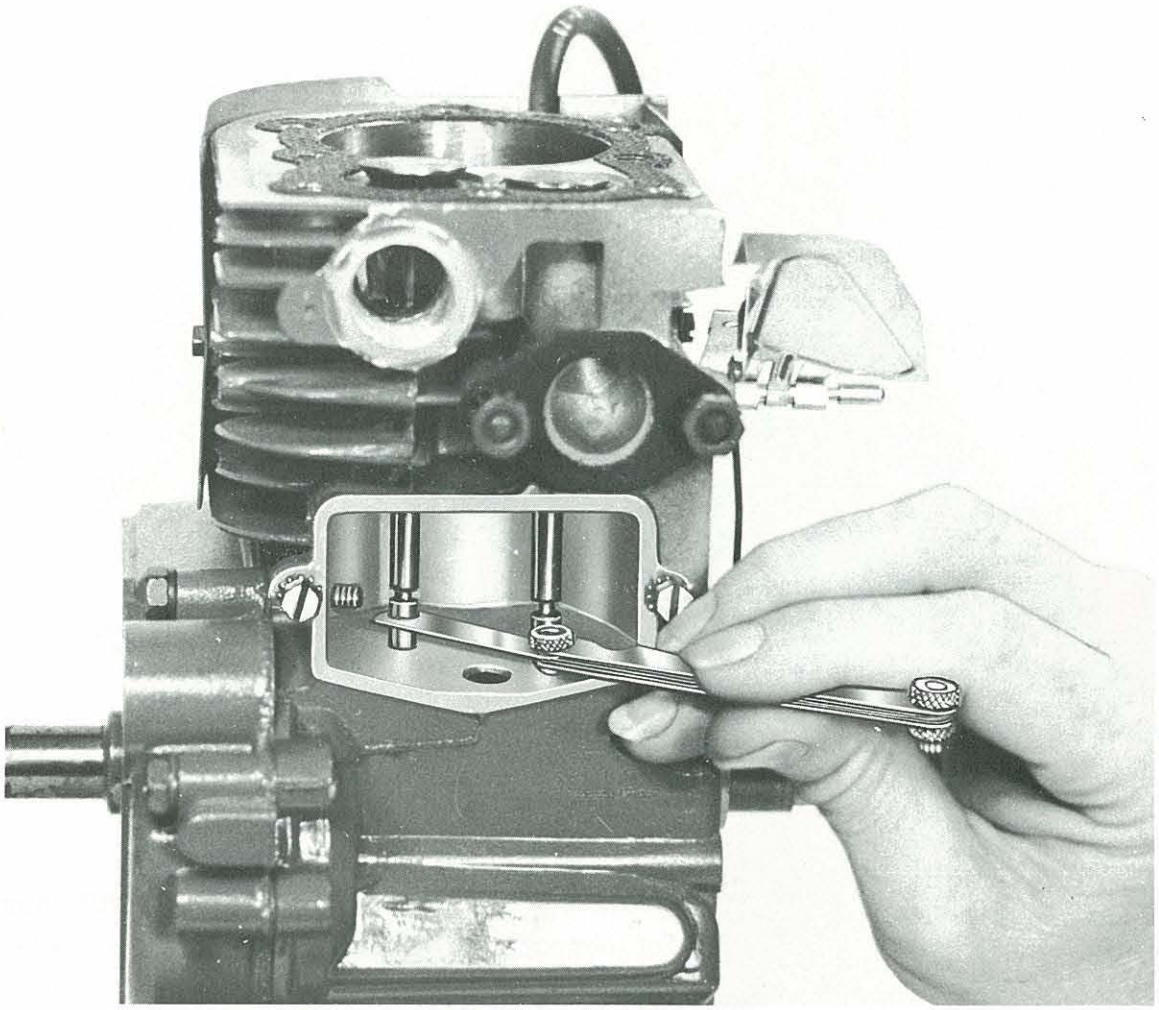

Figure 417

VALVE SPRING AND KEEPER ASSEMBLY

Remove both valves and set them aside. Install both springs, the guide plate and both retainers together. Slip them in the valve chamber until the springs hit the lifters. Use a small screwdriver to lift the back side of the spring over the lifter so the springs are centered on the retainers.

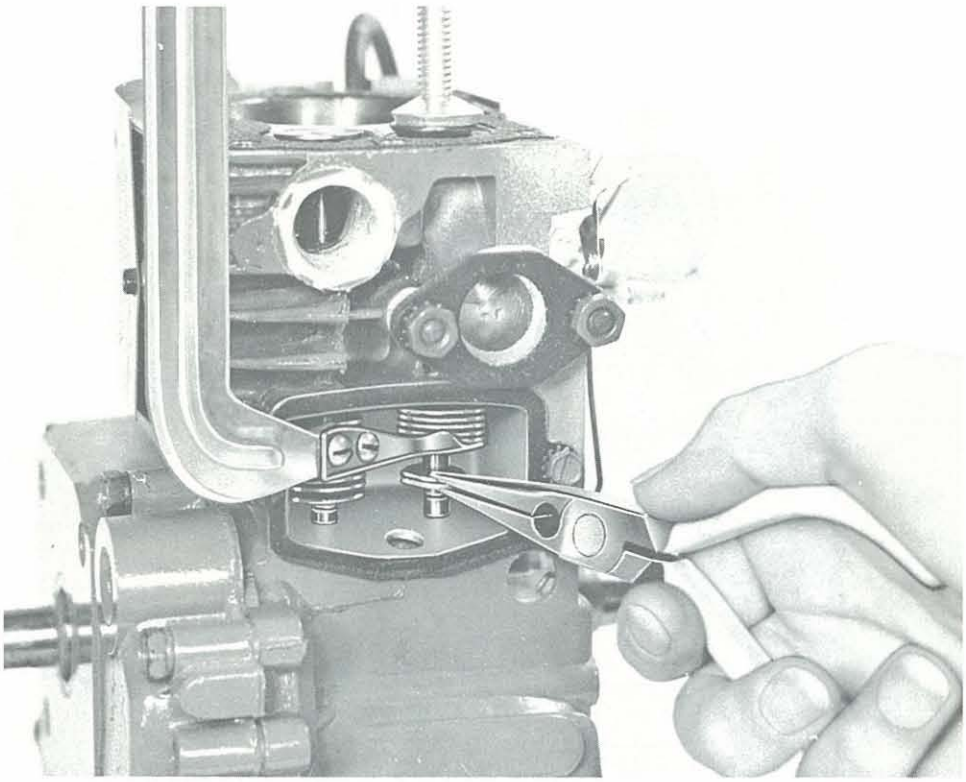

Figure 418

Install the valve lifter as shown in Figure 418. Slip the fork of the tool under the spring and align the screw head on the top of the valve. Compress the spring until you have room to slip on the valve keeper. Do this with needle nose pliers. After the keeper is hooked on the valve stem, release the valve spring pressure. Next, install the other spring and keeper the same way.

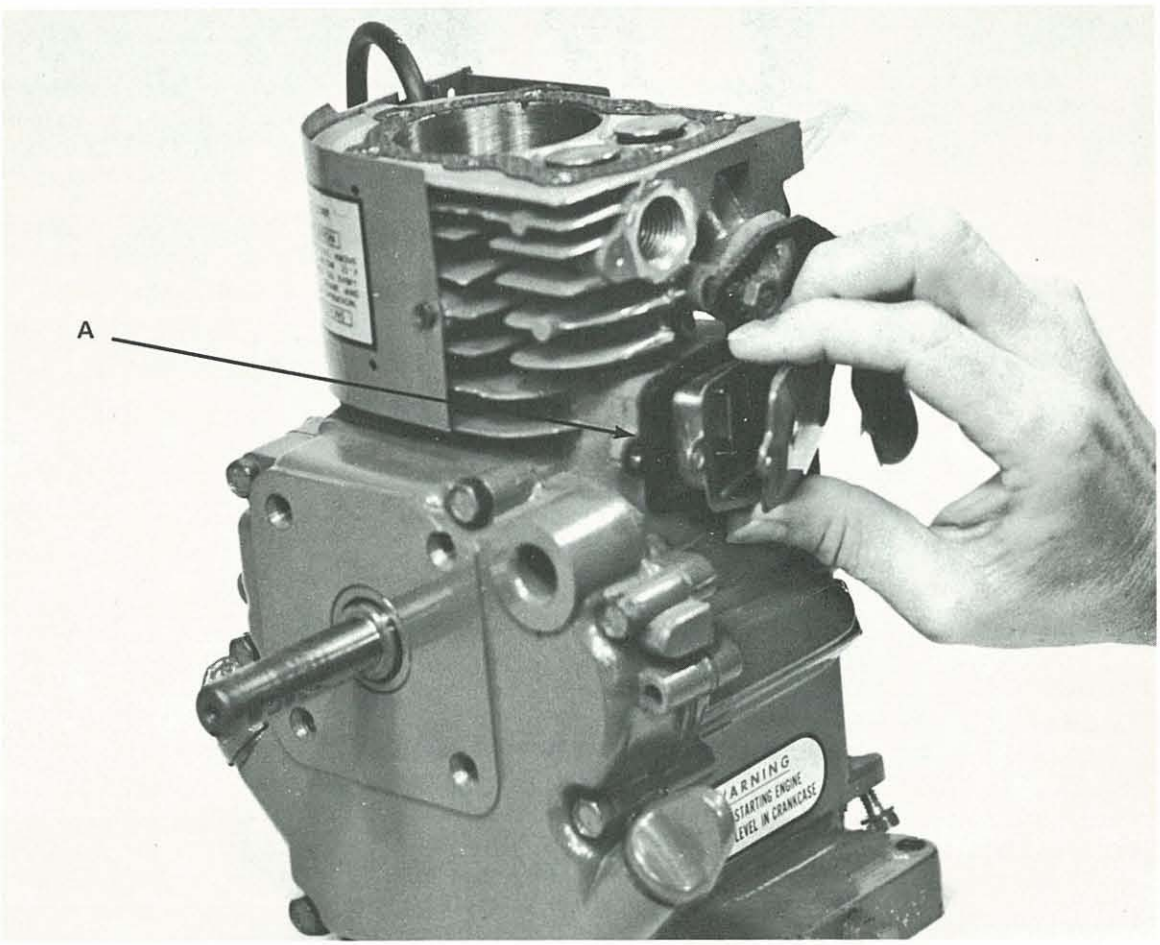

Figure 419

VALVE COVER AND BREATHER ASSEMBLY

Before installing the breather assembly and cover, check the inside of the valve chamber to be sure it is clean and free of any foreign matter. Check the retainers to be sure they are seated with the springs. Turn the crankshaft several turns to see if all parts are operating properly. Next install the breather assembly as shown in Figure 419. There should be a gasket on both sides of the breather as shown at A. Slip the cover plate on and tighten both bolts.

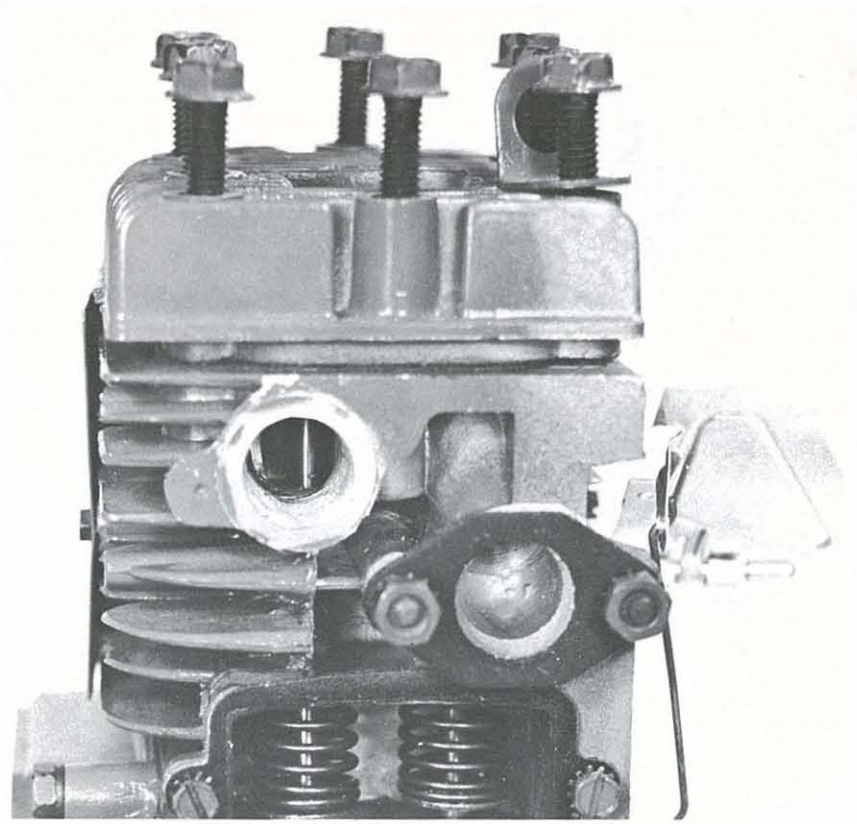

Figure 420

CYLINDER HEAD ASSEMBLY

Cylinder head gaskets should never be reused after they have been compressed. Even though the one you removed may appear to be in good shape, it is always a good idea to install a new gasket once the head has been removed. First lay the gasket on the cylinder block so all the bolt holes line up, then position the head on the cylinder block and insert the head bolts as shown in Figure 420. Pull all the bolts down just finger tight at this time. Do not tighten them. Install the spark plug and grounding clip. You will tighten the head bolts later, after the fuel tank and blower housing have been installed, as it will be necessary to remove four of the head bolts that will hold this assembly.

BREAKER CAM INSTALLATION

The breaker cam should be with your magneto parts. Before beginning to install the cam, examine it carefully. This can only be installed one way, as shown in Figure 421.

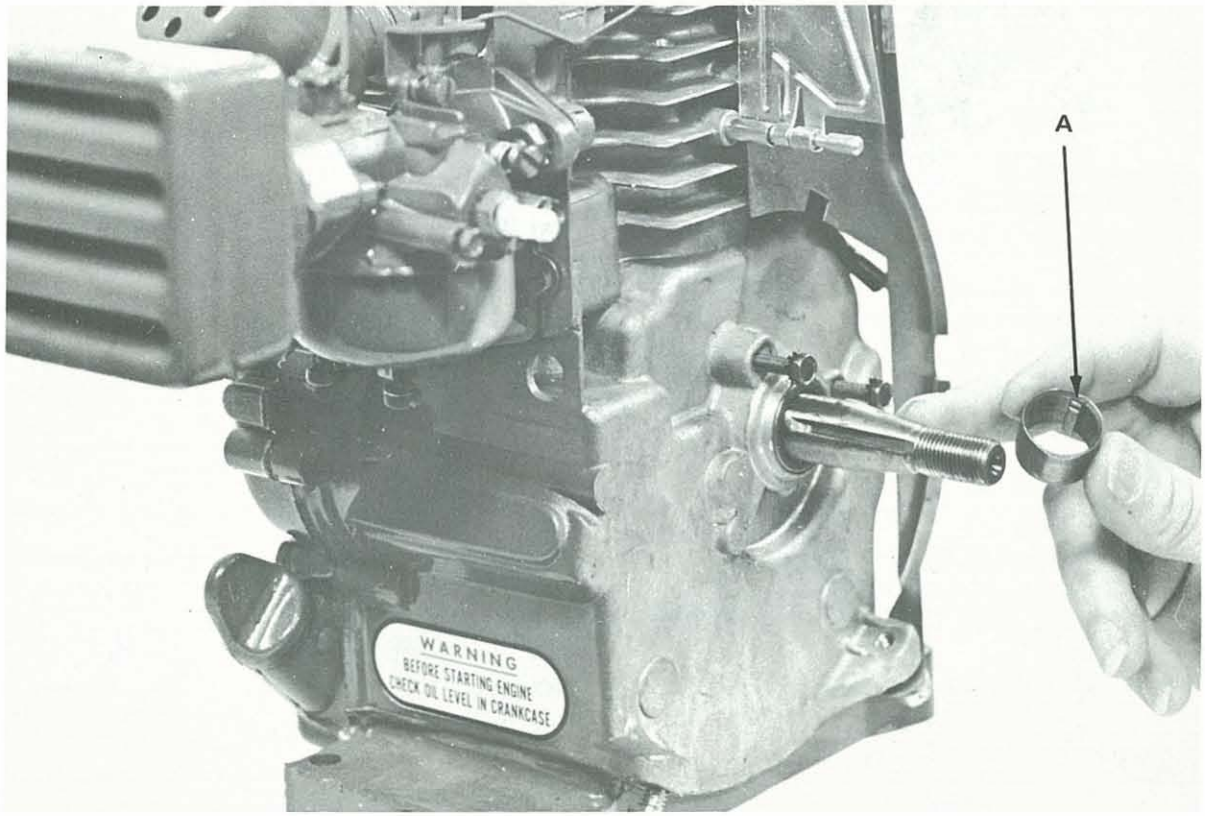

Figure 421

Notice the key inside the cam. One end is flush with one side of the cam and the other side is beveled as shown at A. The beveled side goes toward the engine and fits flush against the oil seal. If you turn the cam around and try slipping it on the shaft, you will notice it will not go on all the way. The bevel side goes toward the engine. The cam design of some engines is made so they will not go on the shaft because of a taper.

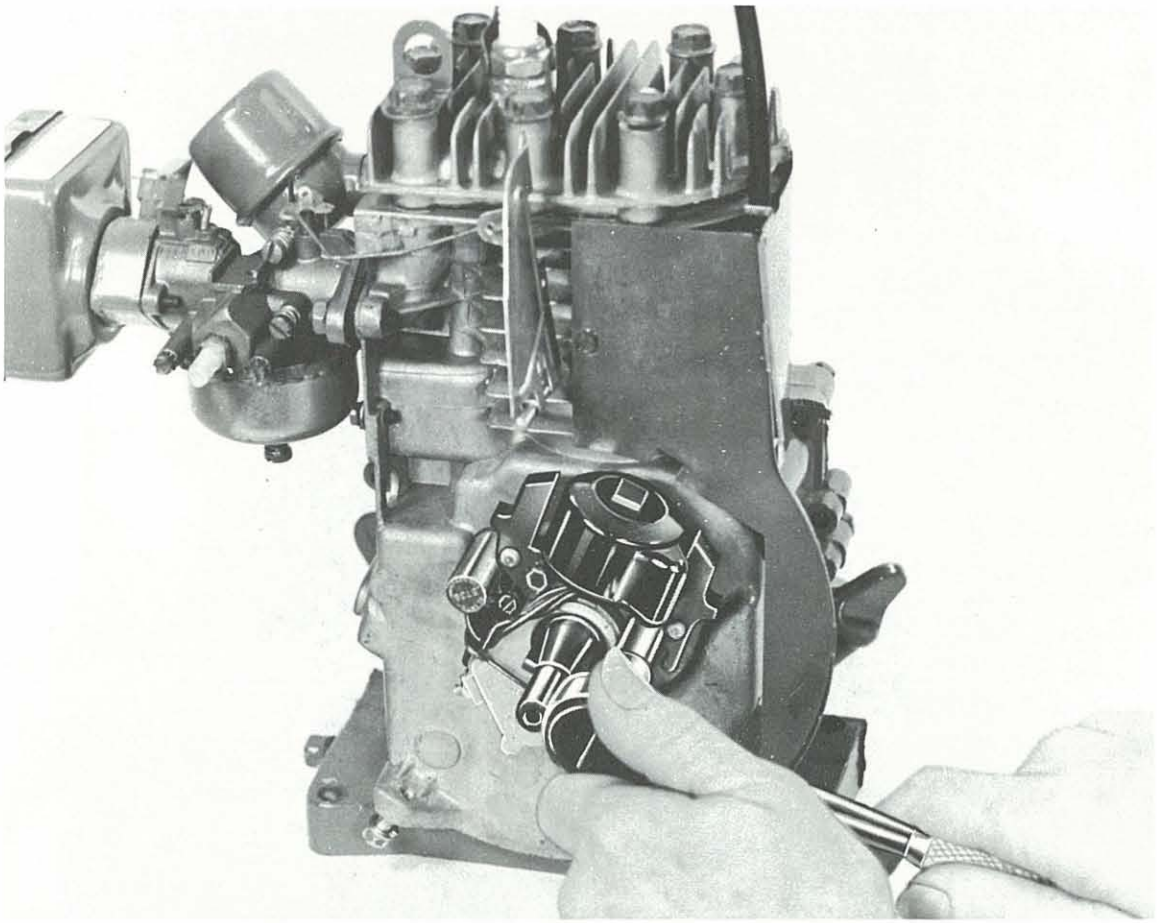

Figure 422

MAGNETO ASSEMBLY

Place the magneto assembly over the crankshaft and breaker cam as shown in Figure 422. Install and tighten the two mounting bolts. Since this magneto does not have slotted mounting holes, it will be in time with the engine. Earlier, in the section on magneto operating principles, we covered the adjustable stator plate mounting. If the mounting holes have slots instead of small holes, it is necessary to mark the position of the magneto before removing to keep from retiming the engine.

IGNITION POINT ASSEMBLY

Earlier we covered the replacement and adjustment of ignition points. It might be a good idea to review this part of the course before attempting to remove or reset the points as shown in Figure 423. These points should be factory set at .020-inch. There is a possibility of the setting being changed through disassembly. Remove the spring retainer, cover plate and dust cover. With the point pivot arm riding on the high part of the cam, check the point gap with your feeler gauge. If the point setting needs to be changed, reset them to .020. As we covered earlier, this sometimes can be tricky since the points may have a tendency to creep while the locking screw is being tightened. After the points are adjusted to the proper setting, install the dust cover, cover plate and spring.

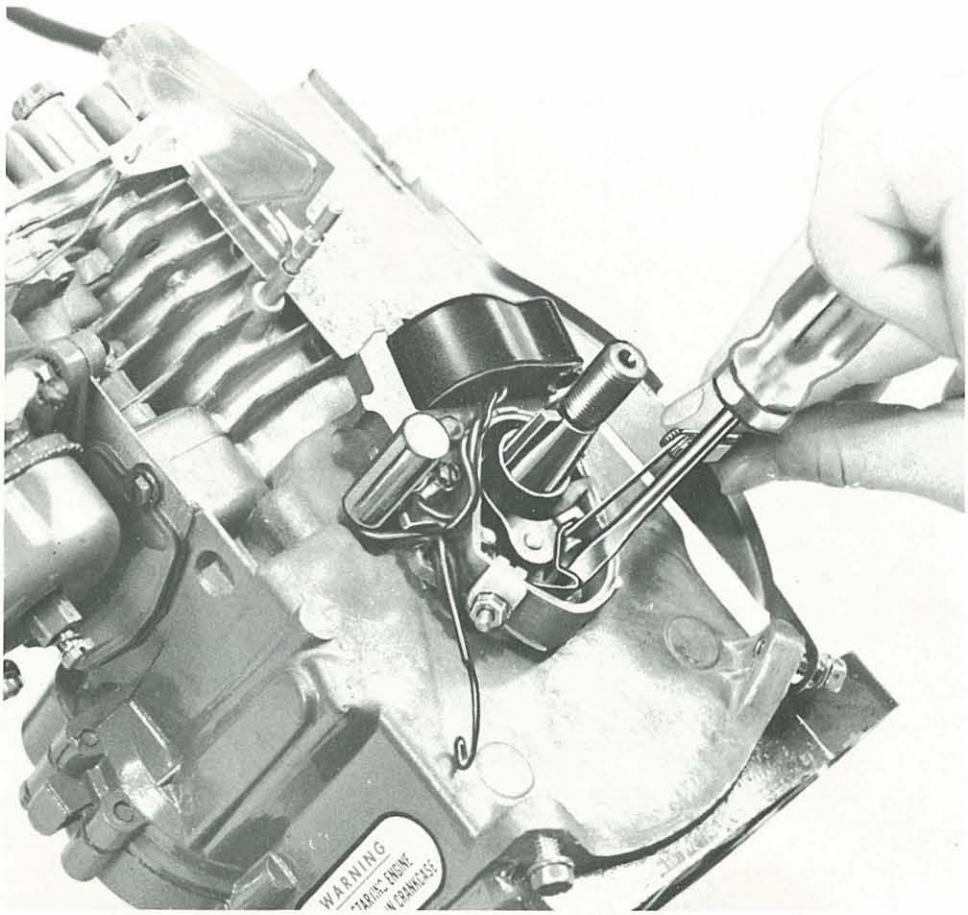

Figure 423

FLYWHEEL AND STARTER CUP ASSEMBLY

First install the flywheel key on the crankshaft. Make sure the keyway and key are free of burrs and clean. Be sure the magneto high tension wire is inserted all the way into the hole in the coil. Line up the flywheel keyway with the key and slip it on the crankshaft. Install the screen, washer and starter cup as shown in Figure 424. Turn the starter cup to be sure it is not riding on the top part of the flywheel air vanes. Next, install the flywheel nut with the bevel edge out and tighten. This nut has a recommended tightening torque of 375 to 400 inch pounds.

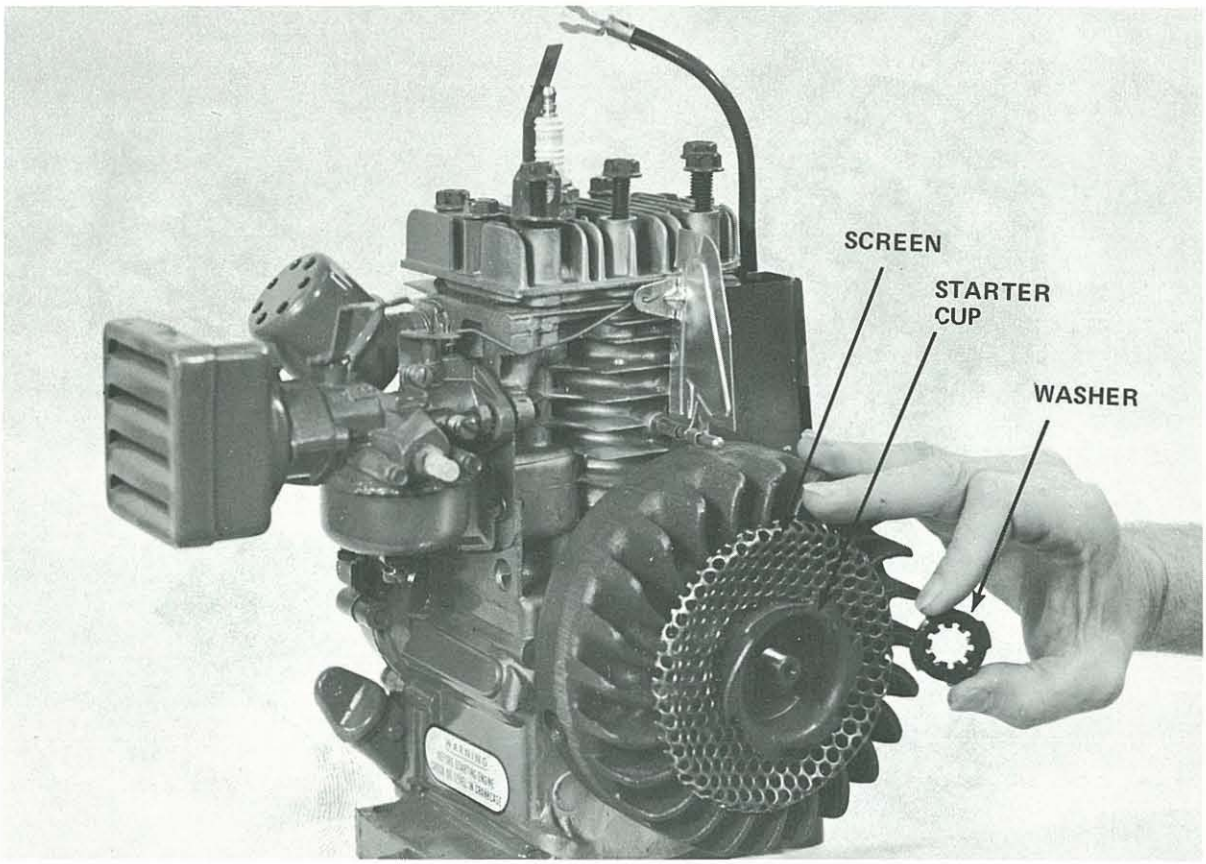

Figure 424

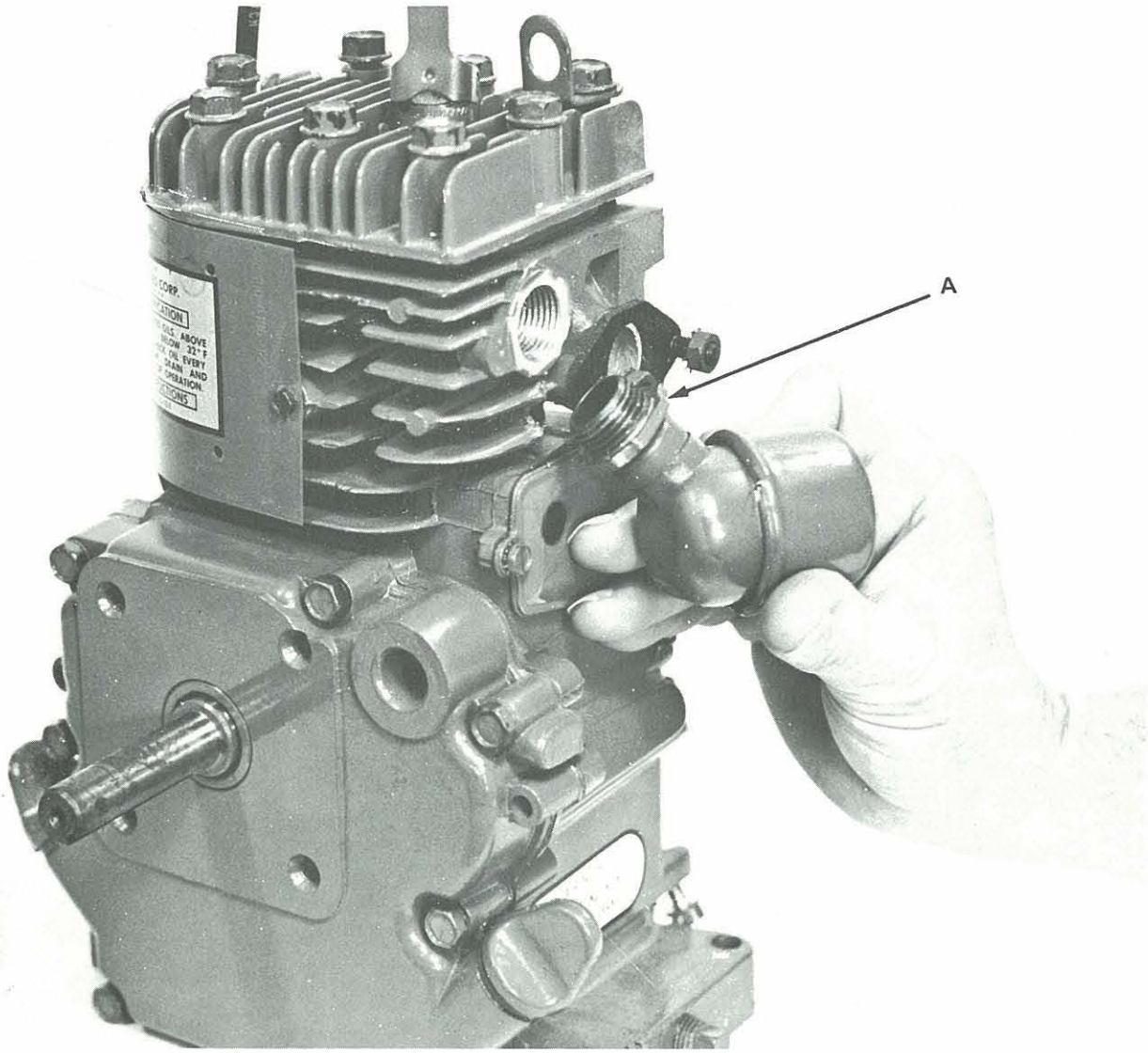

Figure 425

MUFFLER ASSEMBLY

Install the muffler as shown in Figure 425. Turn the lock nut A back on the threads about 3/8-inch and thread the muffler into the cylinder block. Let it extend up at an angle so as not to interfere with the carburetor. The muffler on some engines require a gasket between the muffler and the engine block. Because of the design of this muffler a gasket is not required. After you have the muffler installed, tighten the lock nut against the engine block.

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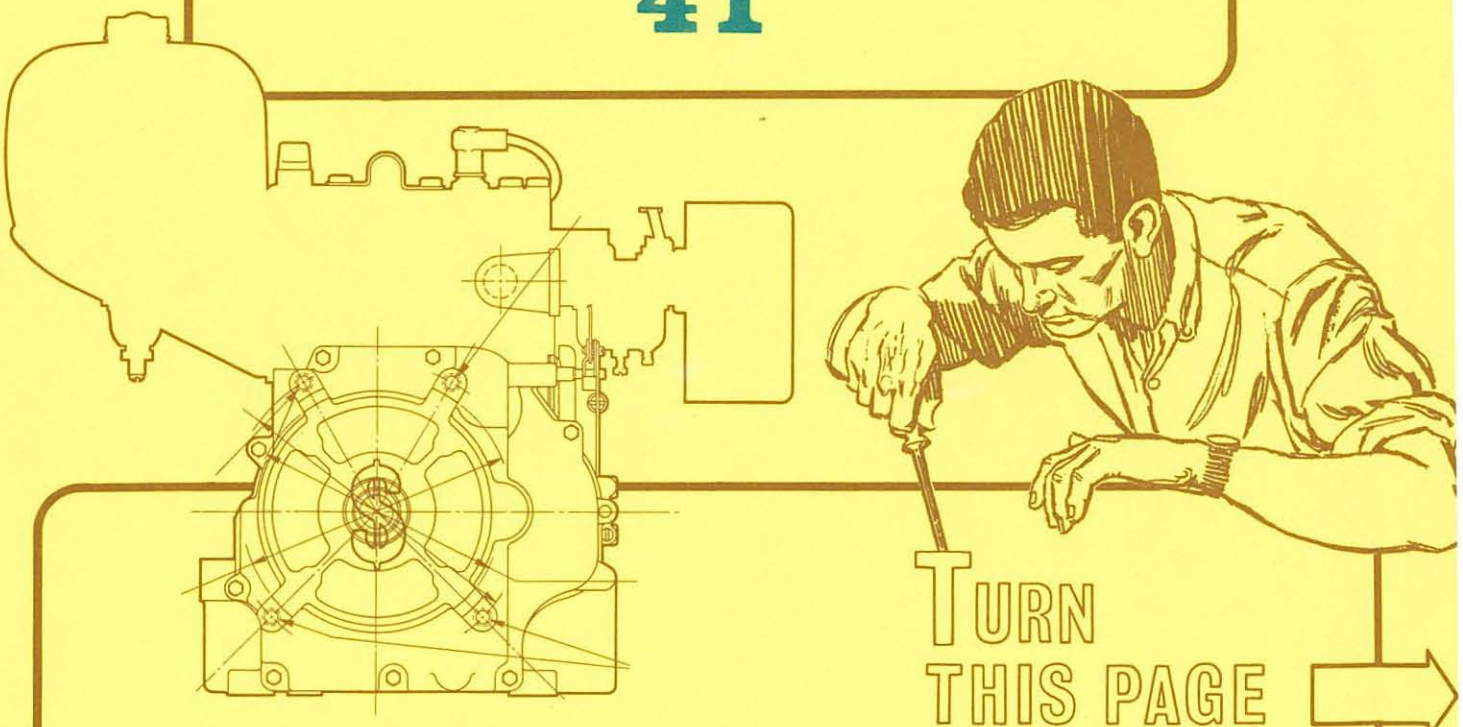

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CARBURETOR DISASSEMBLY AND REASSEMBLY

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AIR CLEANER DISASSEMBLY

Before reinstalling the carburetor on your engine you should take the carburetor apart and disassemble it. First remove the air cleaner assembly as shown in Figure 426.

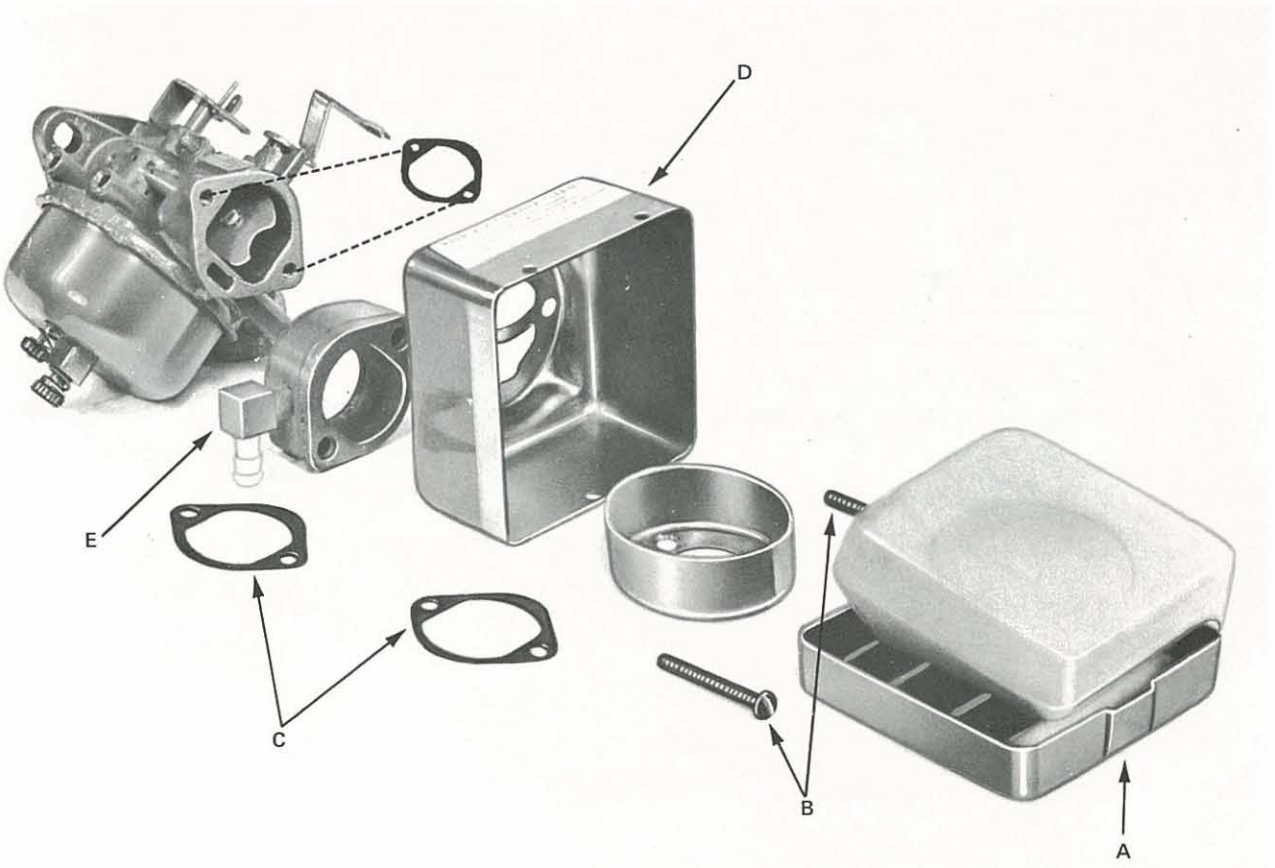


Figure 426

The filter cover, shown at A, is held in place with a friction fit. Some engines will have one or two lock screws. Next remove the two screws, shown at B, and the entire assembly can be removed from the carburetor. Lay the parts out as shown. There are two gaskets shown at C. One goes on each side of the air filter base shown at D. There is also one gasket that goes between the spacers and the carburetor, shown at F.

The spacer shown at E goes between the air filter and the carburetor. The breather hose goes from this part to the valve cover plate, permitting only filtered air to enter this area. Lay out all the air cleaner parts as shown in Figure 426.

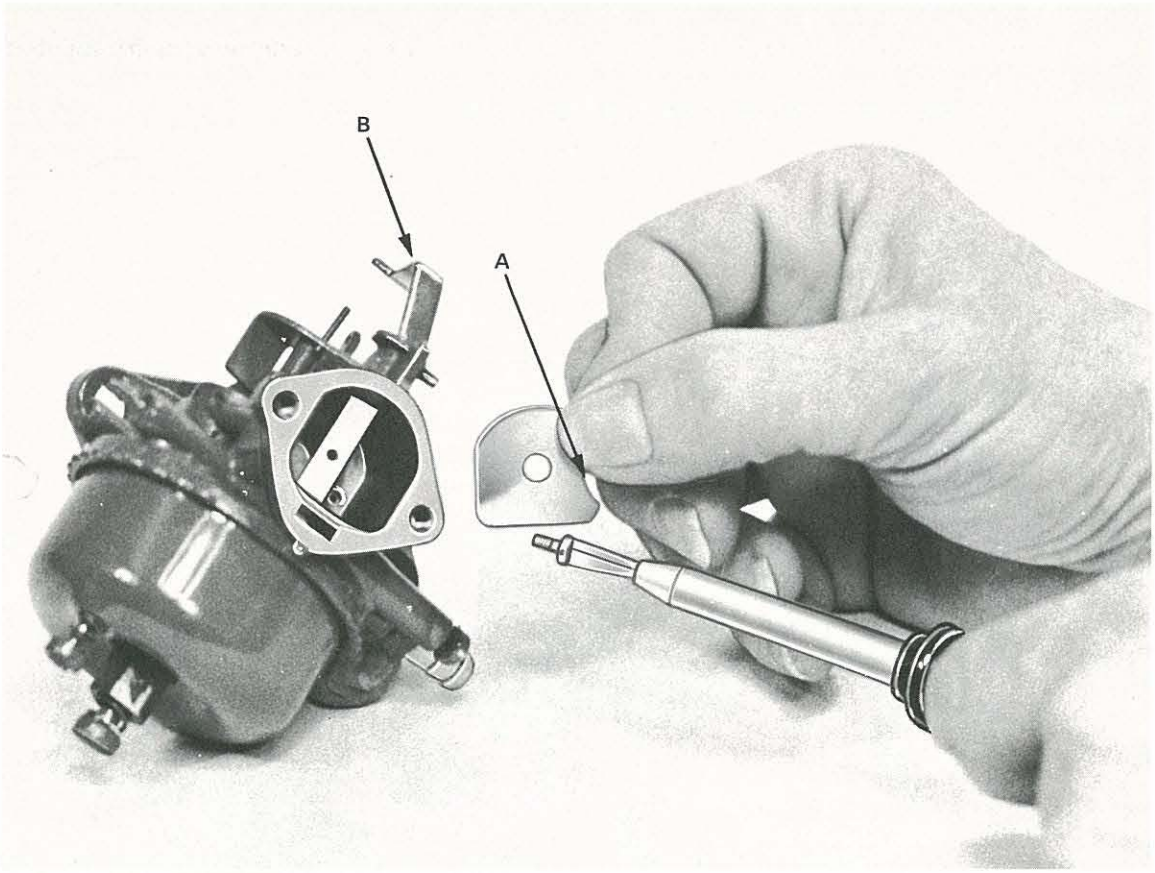


Figure 427

CARBURETOR DISASSEMBLY

Remove the choke plate and lever as shown in Figure 427. Remove the screw holding the choke plate to the choke lever. There is one screw holding the choke plate to the lever. Notice the plate has identification markings on it. These markings must face you as you reassemble it to the shaft and the cut-out part on the plate, shown at A, should be to your right. Pull the choke lever, shown at B, straight out. Lay the choke lever and plate aside.

Next, remove the throttle lever and plate. See if there are any markings on the plate. This plate is held with two screws. Remove the screws, plate and lever and set them aside.

REMOVING SPEED ADJUSTMENT SCREWS

Remove the high speed and idle adjustment screws as shown in Figure 428. Do not get the springs mixed as they are of different tension. If you examine the springs, you will notice one is slightly heavier and stronger than the other. The heavier spring, shown at A, goes with the idle adjustment screw shown at B. Examine the high speed adjustment screw, shown at C. Notice it has a small rubber gasket that rides in a slot on the screw. Do not remove this gasket. These gaskets do show wear or damage and often have to be replaced. Any time they are removed they should be replaced with a new one.

Examine the two screws carefully and notice the difference in them. The high-speed adjustment screw, shown at C, has a longer taper than the idle adjustment screw shown at B.

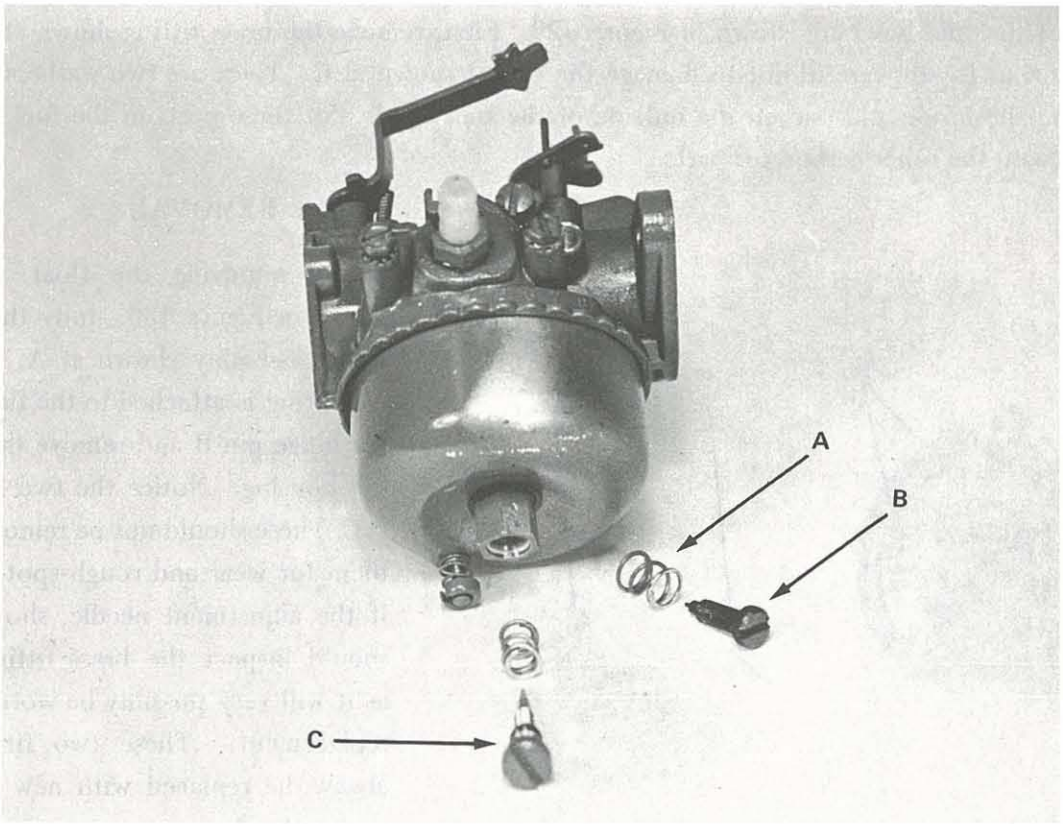


Figure 428

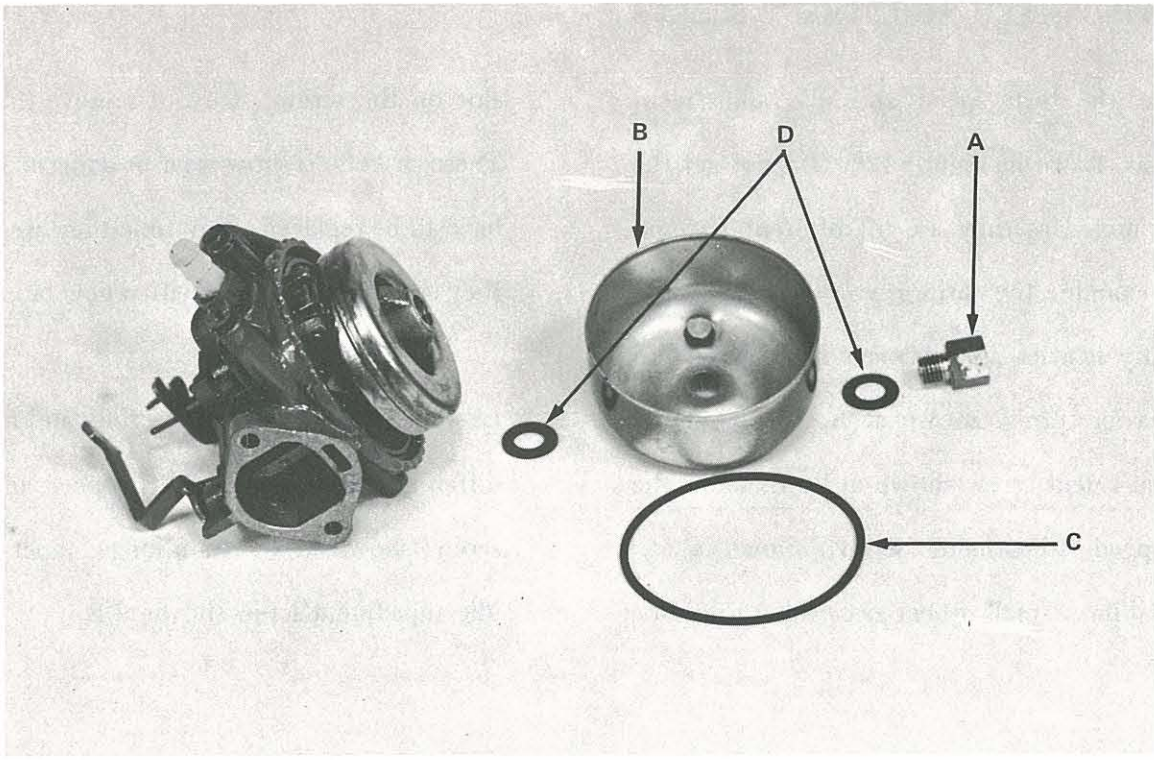


Figure 429

FUEL BOWL REMOVAL

The parts of the fuel bowl are shown in Figure 429. First, remove the brass fitting shown at A. Remove the fuel bowl at B. Be careful not to damage the gasket shown at C. There are two washers shown at D. One goes on the inside and one on the outside of the fuel bowl. Put these parts in the fuel bowl and set them aside with the other carburetor parts.

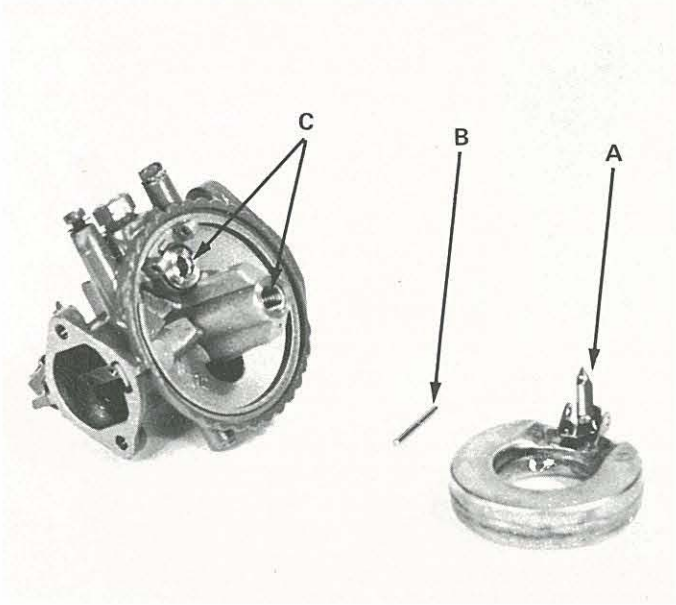


Figure 430

FLOAT REMOVAL

Before removing the float assembly, as shown in Figure 430, study the needle and spring assembly shown at A. Notice how the spring is attached to the float. Pull out the hinge pin B and remove the float from the housing. Notice the two brass fittings at C. These should not be removed. Inspect them for wear and rough spots in the seat. If the adjustment needle, shows wear you should inspect the brass fittings carefully as it will very possibly be worn and require replacement. These two fittings should always be replaced with new ones if they are removed.

INSTALLING FLOAT AND BOWL

Before beginning to reassemble the carburetor lay out all the parts as shown in Figure 431. Attach the inlet needle and spring A to the float B and install on the carburetor body with the hinge pin. Hold the carburetor body upside down and attach the spring and needle to the float. Slip the needle in the seat and install the hinge pin. Turn the carburetor body over and make sure the float rides up and down free. Be sure the needle spring is attached to the float.

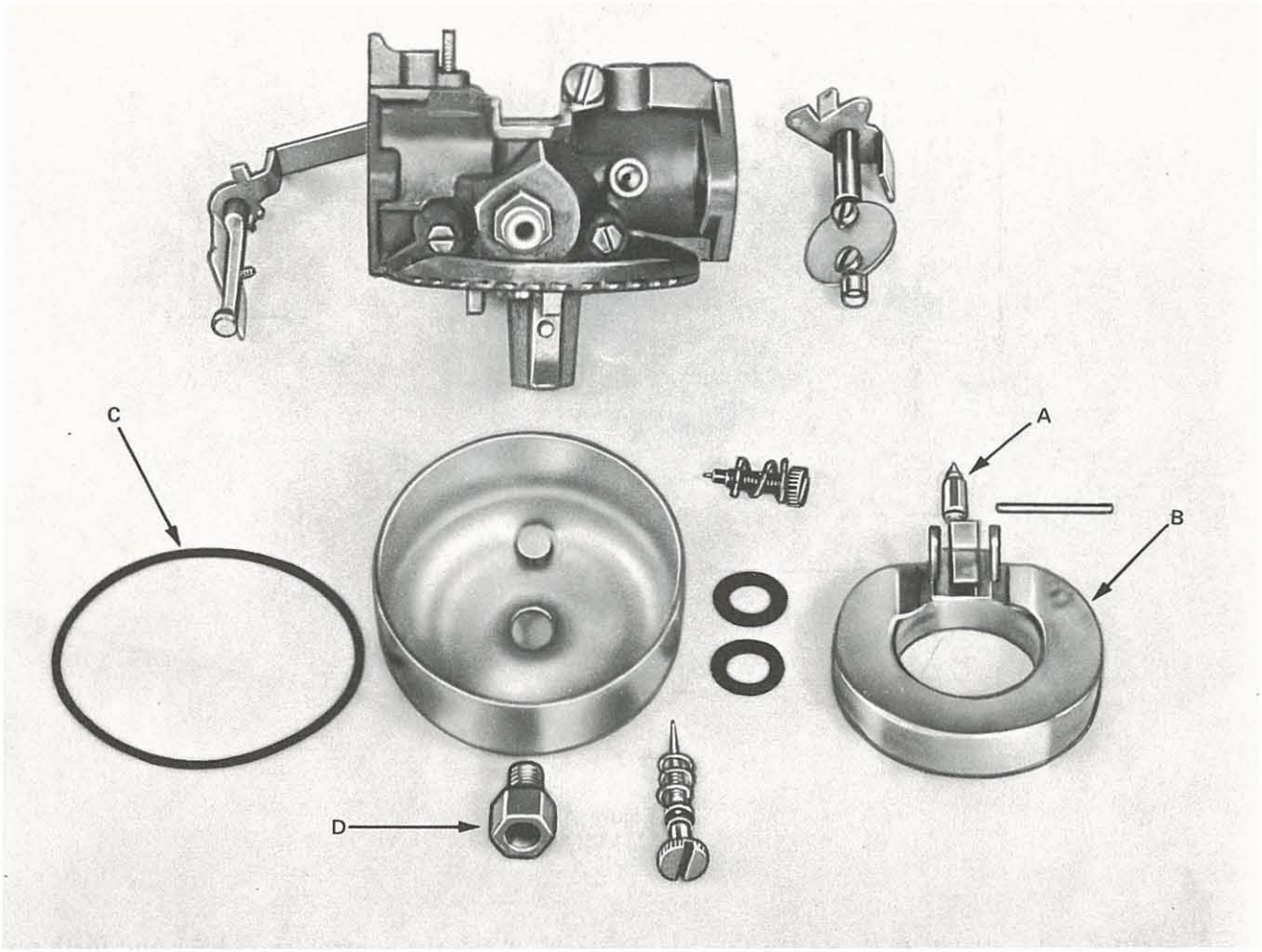


Figure 431

Install the gasket C on the body assembly. Be sure the gasket fits in the groove. Slip the bowl on and push the gasket in place. Remove and check to be sure the gasket is seated properly and then install the bowl. The bowl is held in place with the brass fitting shown at D. Be sure there is one gasket inside and one outside the bowl.

INSTALLING JETS AND CONTROL SHAFTS

Your carburetor should now look like Figure 432. Install the high speed adjustment screw A and the idle adjustment screw B. Turn these just finger tight and then back off two turns. Install the choke shaft C in the housing. Bend the lock spring in the housing so it will engage in the slots in the choke arm. Push the arm all the way down and install the choke shutter D. Be sure the marking on the face of the shutter are toward you when installing. The half moon cut-out in the shutter goes to the right.

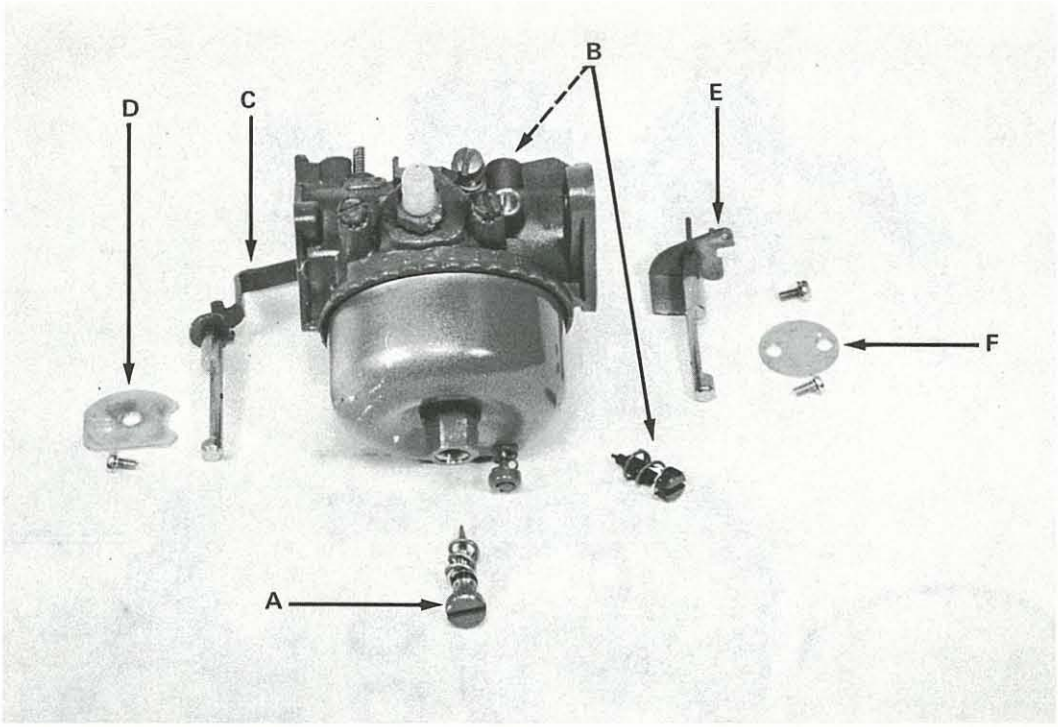


Figure 432

Next, install the throttle shaft E and the throttle shutter F. Work the control levers back and forth several times to be sure they are operating free and the shutters are not binding.

Install the carburetor back on the engine. First, be sure the gasket between the carburetor and the engine is in place. Slip the carburetor on the two mounting bolts and tighten the nuts and lock washers.

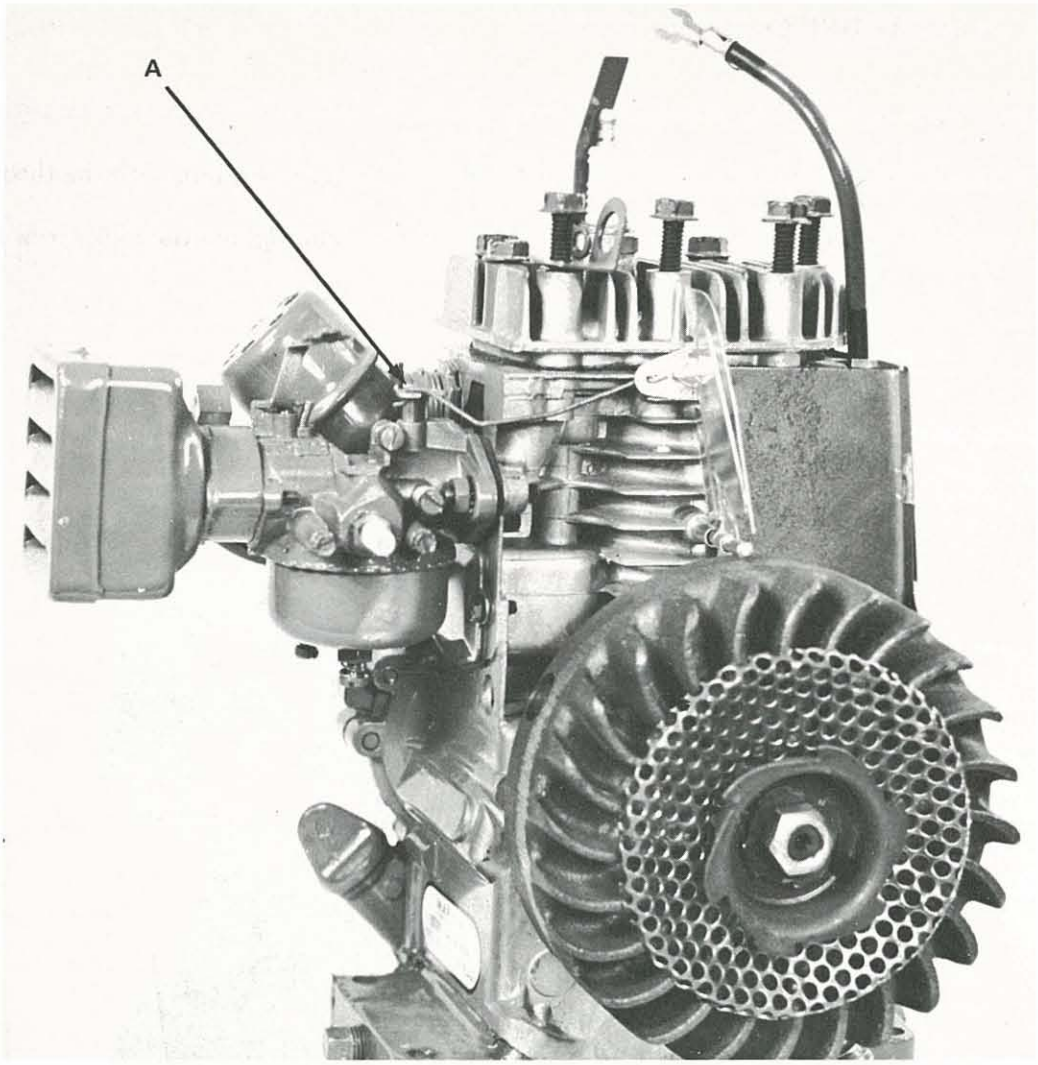


Figure 433

INSTALLING GOVERNOR CONTROL

Install the governor air vane as shown in Figure 433. Attach the control linkage shown at A, to the throttle control shaft. Then attach it to the air vane and slip the air vane on the pivot shaft. Move the unit back and forth several times to be sure the control arm or the air vane are not binding or hitting the engine block.

INSTALLING CARBURETOR CONTROL PLATE

Install the control plate as shown in Figure 434. First attach the spring that goes to the throttle lever and then install the two bolts shown at A. Install the air filter so it does not interfere with the throttle control arm shown at B. Set the throttle control C about midway in the slot and tighten the lock screw D.

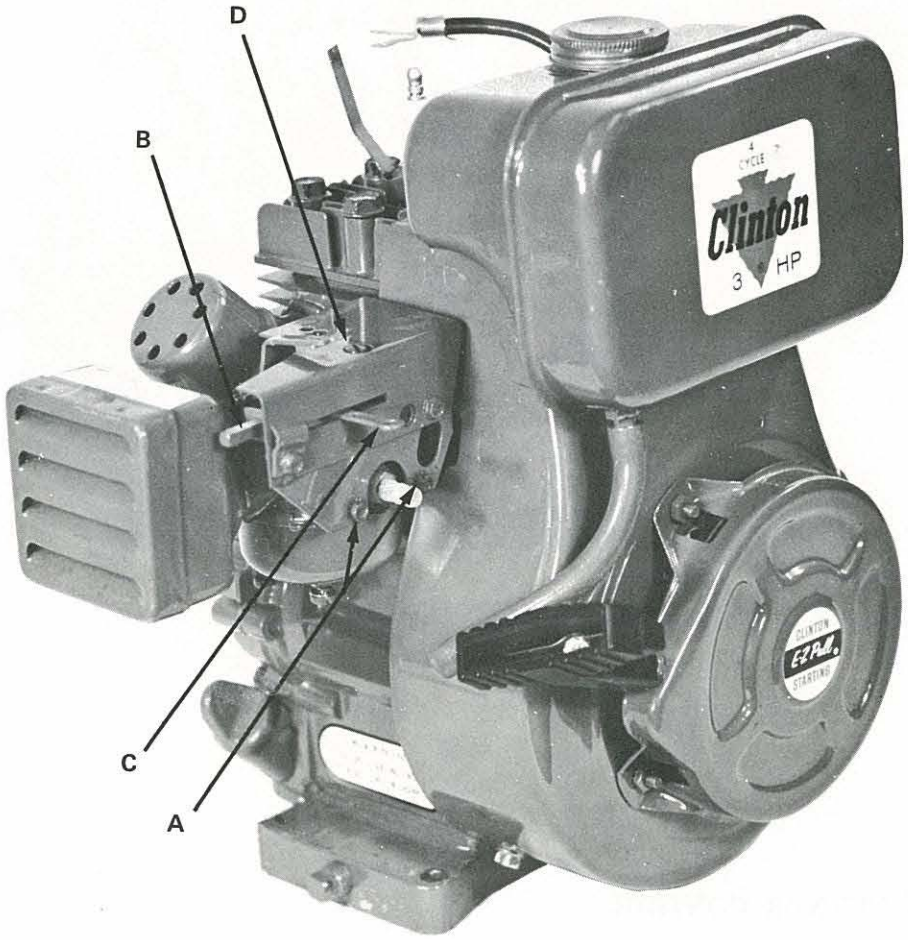


Figure 434

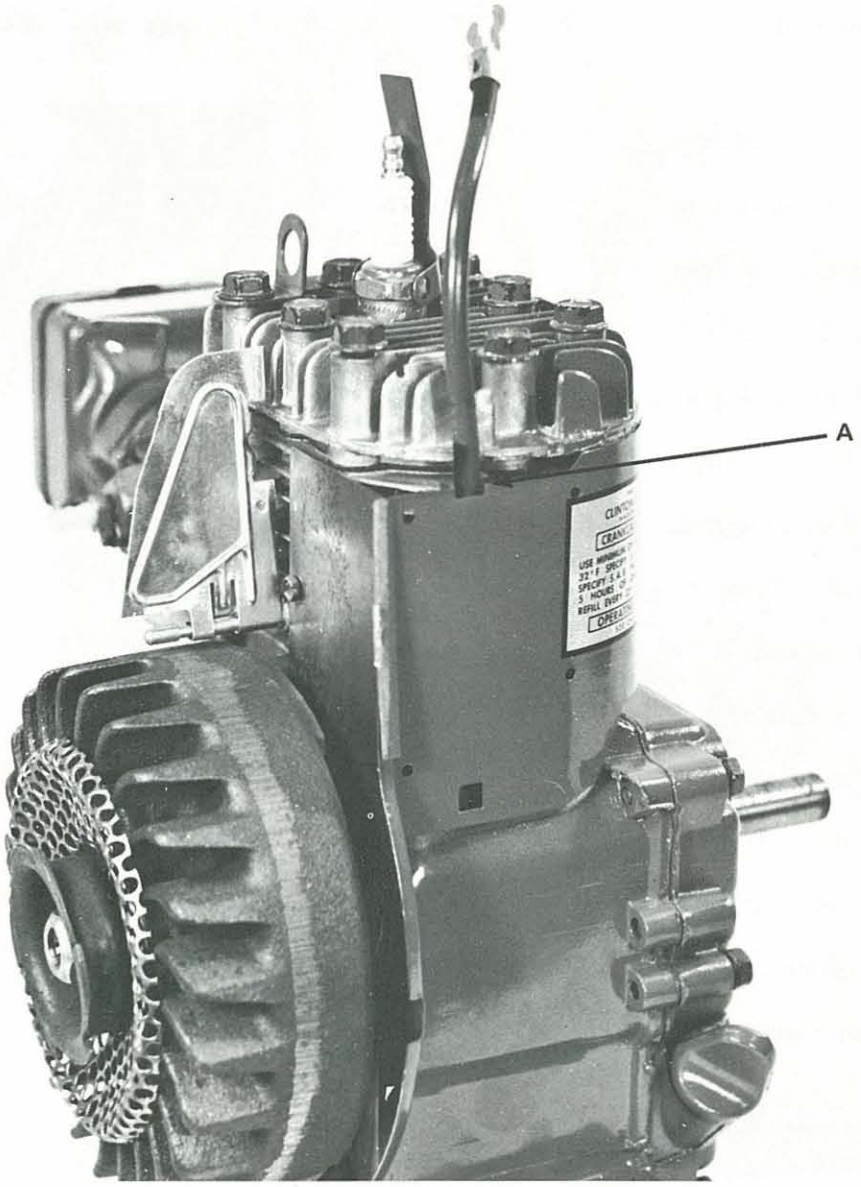


Figure 435

INSTALLING AIR SHROUD

Install the air shroud as shown in Figure 435. This is a two-piece shroud and is held in place with two small bolts and one larger bolt at the bottom that will be installed after the blower housing. Before tightening the two small bolts, locate the high tension spark plug wire in the slot as shown at A.

INSTALLING BLOWER HOUSING

Install the gas tank and blower housing assembly as shown in Figure 436. Remove the four head bolts nearest the flywheel. Slip the high tension spark plug wire through the hole as shown at A. The blower housing goes over the air shroud. There are two small bolts at the bottom of the blower housing shown at B. Start these bolts first, then install the four head bolts. After the head bolts, tighten the two bottom bolts. Tighten all head bolts in the sequence we covered earlier.

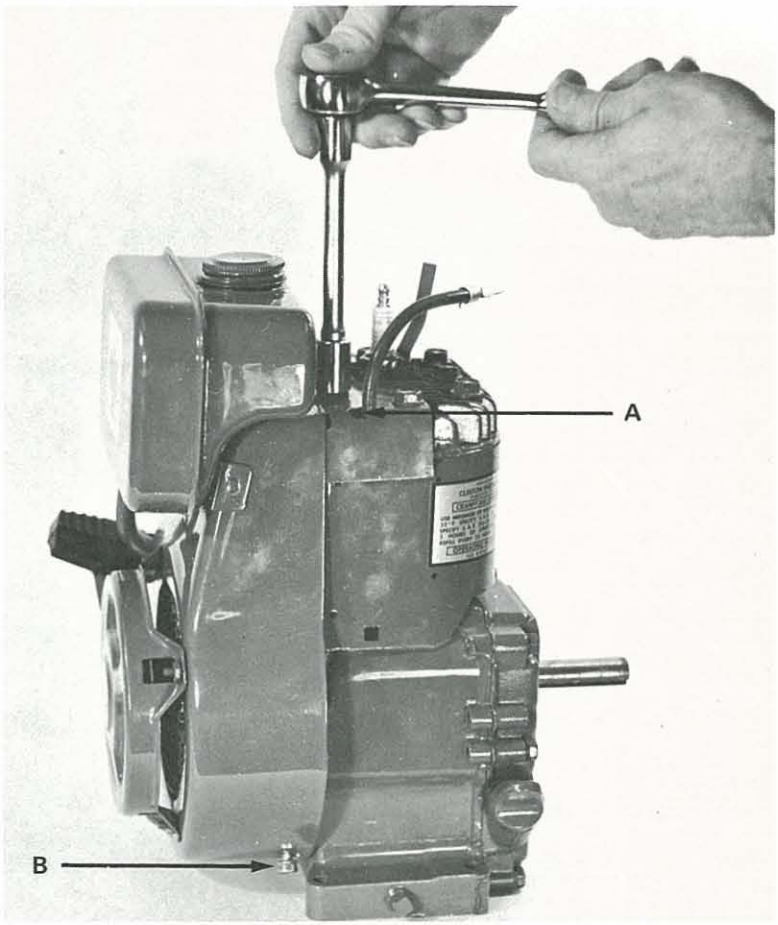


Figure 436

Install the fuel line from the fuel tank to the carburetor and the spark plug wire. Install the air breather hose from the air filter to the breather hole in the valve chamber cover.

At this time the engine should be ready for operation. It is always a good idea to go over the entire engine carefully to be sure all controls work free and all nuts and bolts are tight. After you are satisfied the engine is ready for operation, make the "before operation check" and "engine service check" covered earlier. Your engine should start. If it does not, check it out by following the steps given in the trouble shooting section.

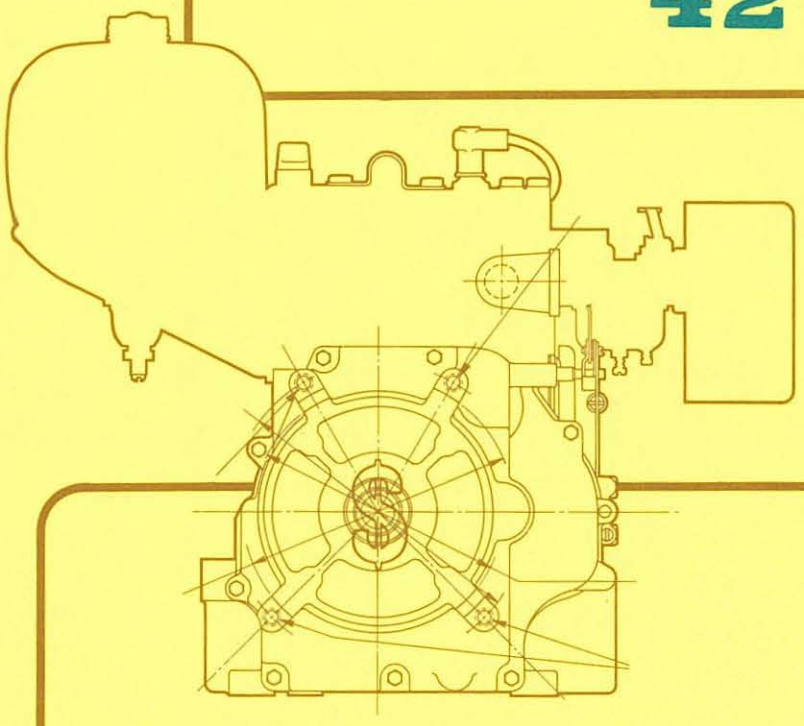
COURSE Of

Small Engine

Repair & Service

LESSON NUMBER

42



TURN THIS PAGE

...and let's find out all about --

OPERATING A SERVICE BUSINESS

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6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

SERVICE CHARGES

Charges for small engine repair and service will vary some in different parts of the country. National averages range from $15 to $25 per hour, plus parts. The charges listed in Figure A should be average for most areas.

	Walk Mowers	Rider
Engine Tune Up	49.95	59.95
Rotary Blade Sharpening	4.95	5.95
Chain Saw Sharpening	9.95 (min)	
Grinding Valves	9.00	11.50
Min. Labor Charge	10.00	12.50
Labor Per Hour	18.00	18.00
Min. Charge	12.00	14.50
Carburetor Overhaul	17.50	20.00
Ignition Repair	18.00	24.00
Valve Job	15.00	18.00
Sharpen and Balance Blade	6.25	6.50
Repair Recoil Starter	9.00	11.50
Repair Impulse Starter	9.00	10.95
Inspection Charge	7.50	7.50
Transmission Overhaul	25.00	32.00
Sharpen Hand Reel Mower	10.00	

Figure A

It is always a good policy to let the customer know when he leaves his equipment what the approximate cost will be. This can avoid a misunderstanding when he picks up his machine. Exact cost can seldom be given until the work is complete since it will depend on the cost of the replacement parts necessary.

REPAIR TAGS

The repair tag is a very important part of your service work. Many engines, lawnmowers and other pieces of equipment look very much alike and can easily be mistaken. You may have several mowers of the same make, model and color in the shop at the same time.

As soon as a customer leaves his equipment you should fill out a repair order form giving complete information on the work to be done, customer name and date he can expect delivery.

The sample repair tag shown in Figure B is divided into three parts. The top part is your permanent record and contains complete information on all work to be completed and parts required for the particular job.

It can also be used later as an inventory control card since all parts used will have to be taken out of your parts inventory.

PERMANENT RECORD

No. _____

Date _____

Name _____

Address _____

Phone _____

Date Complete _____

Equipment _____

Engine _____

Repairs _____

_____

_____

_____

Labor _____

Parts _____

_____

_____

_____

_____

_____

_____

Total

CUSTOMER COPY

No. _____

Date Complete _____

Estimated Cost _____

your
name
address
phone

MACHINE COPY

No. _____

Date _____

Date Complete _____

Figure B

The second part of the repair tag is given to the customer and the third part goes with the machine for identification. Notice there is a space for a number on all three copies. Assign your own numbering sequence giving the same number to all three sections of the tag. If your next job is number 204 you would first fill in 204 on each section of the tag. Next, fill in the current date, name, address and phone number on the permanent record part.

Fill in the date the job is to be completed on the permanent record copy, customer copy and the machine copy. This lets you schedule your work so it can be ready on the promised date. You can tell by the numbering sequence on the machine copy which machine to work on next. Without this you may have ten machines in the shop and begin working on the ones just received instead of the older ones.

The next item on the permanent copy is the equipment. Identify whether it is a lawnmower, snow-blower or other equipment. The engine is next. Show the make of the engine and then list the repairs needed on both the engine and equipment. Before working on the engine you will want to look at this part to be sure what service work is necessary. After several days in the shop you may forget what work was to be done on this particular engine.

After the work has been completed fill in the labor charge, part number and selling price of all repair parts used. The total of the labor and parts is the total charge to the customer. When the customer picks up his equipment match the customer copy record number with both the machine copy and the permanent record copy to be sure of the right price, machine and customer. The two bottom copies can be destroyed and the top permanent record copy should be kept for your records.

INVENTORY CONTROL

One common problem among many small repair shops is not having parts on hand to make repairs. It is very easy to let a shelf of stock get too low and run out by trying to remember to reorder parts when you are removing them for repair. The time to check on your inventory stock of parts is when you are doing your book work and not when you are doing repair work.

Engine Make _____ Part Cost _____

Part Name _____ List Price _____

Part No. _____

Date	In	Out	On Hand		Date	In	Out	On Hand

Figure C

Figure C shows a simple inventory control card that is easy to use and if kept on a daily basis it will tell you exactly how many of any individual part you have on hand, how many you have used in the past few weeks or months and when you should reorder. These cards can be filed by engine make.

Next fill in the name of the part for that engine and the reorder part number. You should also enter your cost of the part and the list price you will charge the customer. When you reorder parts you should check your cost against this card listing to see if the price has gone up. If it has you would want to adjust your list price accordingly.

When your supply parts come in, enter the date they were received and the number received in the column "IN". At the end of each day enter the number of parts used in the "OUT" column. The difference between these two columns is the balance you still have on hand in your inventory.

Engine Make Clinton Part Cost 1.15

Part Name Points List Price 1.85

Part No. 135-7-500

Date	In	Out	On Hand		Date	In	Out	On Hand
1-15	30	3	27					
1-18		5	22					
1-21		2	20					
1-22		5	15					
1-23		5	10					

Figure D

Figure D shows some of the points a typical inventory control card can tell you. Under the date of 1-15 we received 30 sets of points for Clinton engines with part number 135-7-500. The cost of these parts was $1.15 per set and the selling price to the customer is $1.85 per set. That same day we used 3 sets of points repairing engines, leaving a balance of 27. As the parts used each day are posted it shows the exact balance we should have on hand in our inventory. This card gives an indication of the quantity of parts we should order. Notice between the dates of 1-15, when we received the shipment of 30 sets of points, and the date of 1-23, we have only 10 sets left in stock. That means 20 sets of this particular part were used during this short period. This would indicate a rapid turnover and would justify buying these parts in larger quantities.

Some inventory cards may show only one or two parts used in this period or even longer, which would indicate a slow moving item not requiring as much stock. The locality in which your service work comes will determine to some extent the amount of stock to carry for an individual part.

There is no definite pattern in repair part sales for any given area, however, your inventory control cards will start showing a pattern after a short period.

PARTS STORAGE

The proper storage of parts is very important in order to operate an efficient repair shop. Much wasted time can be spent looking for the proper part if they are not properly organized. One parts cabinet of the approximate size shown in Figure E will hold the working inventory of the average shop. First the cabinet should be divided into sections for each of the major engine manufacturers. Briggs, Clinton, Tecumseh and Lawnboy should each have separate sections as shown.

Each row of divided shelves should contain the parts associated with one area of the engine, such as ignition. carburetion, gaskets and others. If you set up and mark the bins as shown it will be very easy to pull out the needed part. Efficient access to parts can save a considerable amount of time in the course of a day's work.

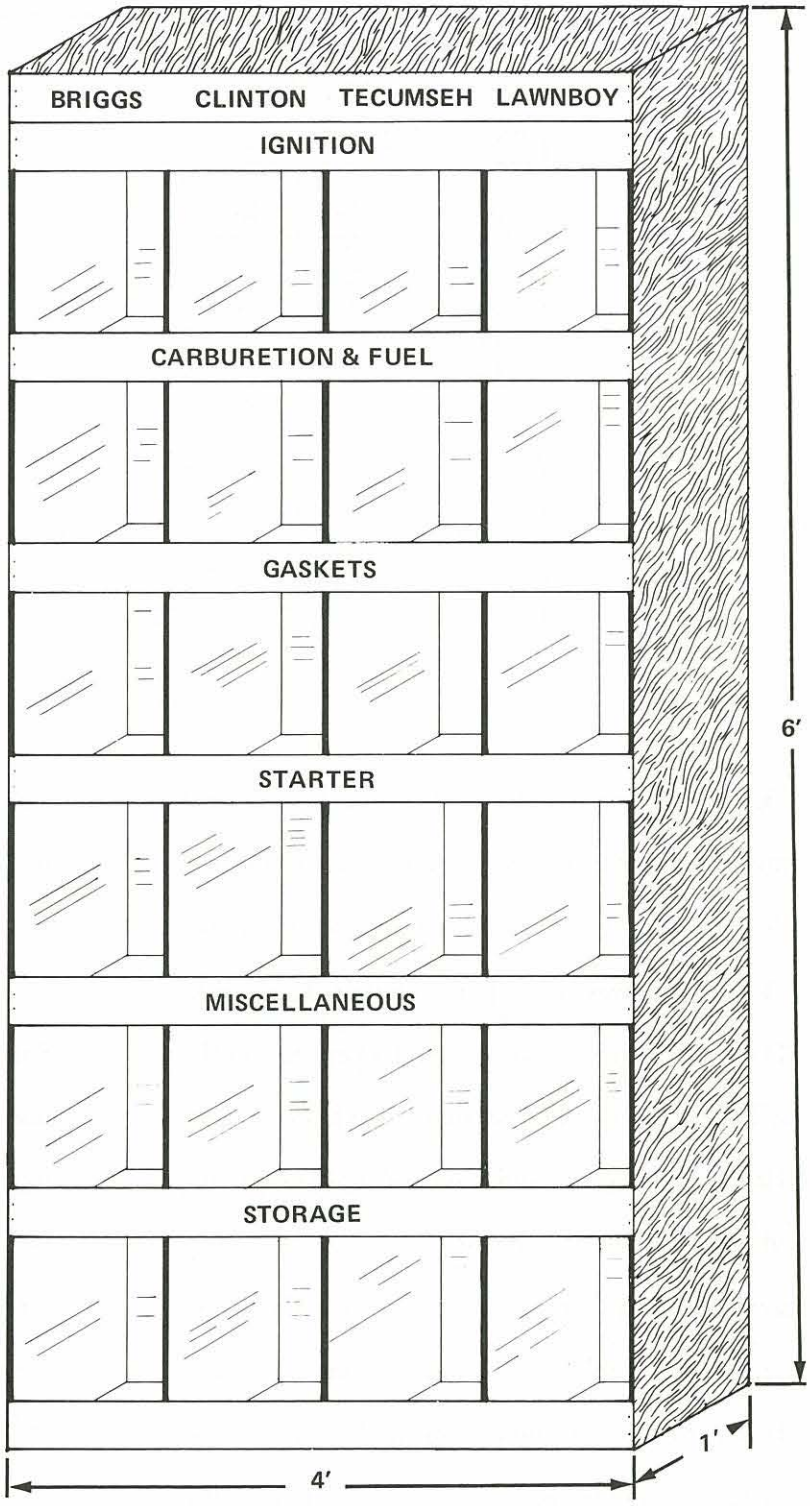


Figure E

A cabinet similar to the one shown in Figure E can be made easily from 3/8 or 1/2 inch plywood with 1/4 inch dividers or an existing set of shelves can be arranged in this manner. The bottom two shelves can be made as shown or left open for miscellaneous parts and storage of excess inventory.

BE FAIR

People are all alike in one way. They respect those people who COMMAND RESPECT. Don't let mechanics or sales people tell your customers you have no ethics. Build your business solidly on the respect of the community, and you will not lack for business. When mechanics or other personnel run down any product a customer has bought, they are, in effect, insulting the customer's previous good judgement, with resultant bad public relations for you.

BE HELPFUL

If the customer's mower is an off brand, with no way of getting replacement parts, don't show your chagrin or disappointment at losing a repair sale. Remember, your treatment of this customer reflects on your standing in the community. You might try looking around some of your stock of old junk mowers and engines for a part that may be just as good as new for a replacement.

EXTRA SERVICE

Nowadays, when a service mechanic calls on a customer to fix an appliance the good mechanic not only fixes that appliance, but visually checks every other appliance in the house. That's smart business, and good public relations too. Not too long ago, terms like "public relations", and "customer goodwill" were terms confined to "Big Business" . . . not related to the average Service or Repair Shop. Today, aggressive servicemen are not only "Customer Relations conscious", but are also training all personnel in the proper handling of customers. One of the finest ways to build good will, is by offering a few small "extras" in the way of service that add up to satisfied customers . . . customers that will tell their friends . . . and always come back.

- ★ Wipe off the mower before handing it over to a customer. A small thing to do, but no customer appreciates handling greasy equipment.
- ★ Use a little touch-up paint and grease the wheels.
- ★ Advise the customer of any signs of possible trouble you might have discovered when working on the equipment.
- ★ A little friendly advice on the operation of his equipment is welcome to many customers.

SUCCESS AND FAILURE

The difference between *success and failure* in the Service Business is often the difference in the relationship between the serviceman and his customers. Not all customers are easy to get along with. The customer is NOT "always right", even though some would like everybody to think so. TAKE IT EASY when you run into this type of customer. USE FINESSE. Don't let the "tough" customer get your goat. Some people have to let off steam. Wrong or NOT – he still is the CUSTOMER . . . the guy who keeps you in business. Believe it or not . . . even today CUSTOMERS like to be treated like *CUSTOMERS.*

LAYOUT FOR EFFICIENCY

Your Service Shop may not be a big industrial plant, but streamlined "production" is just as important to you from the standpoint of $$$. Make repair work "FLOW" *through* the shop, as in a production plant. Don't waste time by going *back* and *forth.* A neat, clean orderly layout saves time and makes money because work moves faster.

USE MODERN TOOLS

Modern tools are money makers for the busy shop. Special machines need extra consideration in shop layout, to make them accessible to all personnel. The use of power tools such as ELECTRIC WRENCHES for former hand operations, speeds up work, adds to capacity, and makes each job easier and more profitable in the end.

STORAGE

Keeping mowers spread around in valuable working floor space in your shop not only consumes space, but makes working in the area more difficult and dangerous. MAKE BINS for repair mowers. Keep the mowers off the floor and in the bins. NUMBER THE BINS. Write the bin number on all papers used, including the customer's tag. If an engine is removed, leave the mower in the bin and put the bin number on the engine.

WORK AREA

Another way to save time in your shop is to put up a gate and a sign keeping customers and others OUT of shop areas. They can waste your time, and get in the way . . . and accidents CAN happen.

ADVERTISING

Any Service Shop that has been successful, and built a good business has had to advertise. Your customers will advertise for you, through . . .

– YOUR GOOD WORK

– A GOOD CLEAN SHOP

– COURTESY TO CUSTOMERS

And don't forget, FAIR PRICES SPEAK LOUDER THAN ADVERTISING WORDS.

YOUR BEST ADVERTISING IS A SATISFIED CUSTOMER

We've talked about satisfied customers, friendly retailers, and neighbors of satisfied customers as all being good advertising and good business-getters. In addition, there are other effective means of advertising your business through display and promotion channels. These should not be overlooked. WHEN to advertise . . . HOW to advertise . . . HOW MUCH to spend . . . these are all questions that have to be settled by the individual repairman to suit his particular business needs. However, a few suggested means of advertising your business are listed below. There are many others.

SERVICE SHOP ADVERTISING IDEAS

DIRECT MAIL ADVERTISING – Business reply cards can be sent to your regular customers as well as to retailers for off-season work. Keep a list of customers and prospects for this purpose as well as for other direct mail advertising.

PHONE BOOK ADVERTISING – A listing of your Service Shop in the Yellow Pages is a proven form of advertising and known source of business.

NEWSPAPER ADVERTISING – or advertising in your neighborhood "Shopper" can be a profitable source of business. Often times one ad serves to attract business for some time to come. Classified listings in daily newspapers; and door-to-door circulars are also effective.

SIGNS AND DISPLAYS – Let people know where you are and WHO you are. Keep windows and store fronts clean and attractive. Display accessories and tools.

EXPANDING YOUR BUSINESS WITH OTHER SERVICES

Many operators of other service businesses find small engine repair a profitable addition just as many who start with engine repair find that they can add related services.

One of the best combinations is small engine repair and sharpening. Many of your customers have regular needs for both of these services and if they are already calling on you for one, it is natural that they will give you the other when you let them know that you can supply it.

CONGRATULATIONS

As a graduate of the Belsaw Institute you are entitled to free consultation on both small engine repair and general business questions. You will receive the Belsaw Bulletin, on a regular basis, without charge. This publication is mailed five times each year and goes to over 250,000 customers and Belsaw Institute Students. You will be kept up to date on all new products, ideas, customer and student suggestions on new ways to do things, along with many helpful hints on how to make your business more profitable.

Again, congratulations on completing the Belsaw Course in Small Engines. You are now on the way to a permanent, pleasant and profitable career in a respected profession. Give it your best efforts and the results will be more than satisfactory to you and yours.

HOW AND WHERE TO GET BUSINESS

Perhaps your objective was to learn about Small Engines and to fix and repair your own small engines. If so, fine!

But, if you're like many students taking the Belsaw Small Engine course, you may be looking for income from what you've learned.

As we told you in the introduction to this course, the objective was to provide you with the basic knowledge to repair Small Engines so that you can use this knowledge to obtain added income through spare time efforts.

The following information has been developed to help you if you are interested in spare time or full time income in Small Engine Repair work.

INCOME OPPORTUNITIES

A. SMALL ENGINE SERVICE SHOP

Before you have your own shop in operation, a service shop may be interested in hiring you part or full time as they are often overloaded with work, particularly from May through October (depending on the area of U.S. in which you are located). Small Engine Repair Shops service many types of equipment including mowers, chain saws, tractors, generators, etc. You can get some good, practical experience in a service shop, and learn first-hand how a business operates.

B. DISCOUNT STORES (K-Mart, Zayre, Arlans, Belscot, Skaggs, Venture, etc.)

Offer your services to the garden shop or equipment sales manager.

1. Arrange to assemble, test, and demonstrate each piece of power equipment the discount dealer sells.

2. When the customer or store brings the product to you, put in gas, oil, grease, etc., make sure customer knows how to operate unit properly.

THIS IS A SERVICE MANY STORES NEED. Normally they don't want the responsibility. They want to *sell, not service.* Usual fee per product is in the range of three to five dollars. The customer will come back to you for tune-ups, parts, and general service, *increasing your business.*

NOTE: Have cards printed to give out. Better still, have gummed stickers made and attach to product for repeat business.

C. RETAIL DEALERS

(Hardware stores – Lawn and Garden Shops)

Some retailers mistakenly think service business is not profitable. Offer the same service as to Discount stores.

D. RENTAL DEALERS

Most rental dealers have been forced into service work, however, you may find you can help on an overload basis.

After you have your own shop in operation, you will want to make contacts and prepare to serve specific types of customers who use specific products. Listed here are a few ideas to help you.

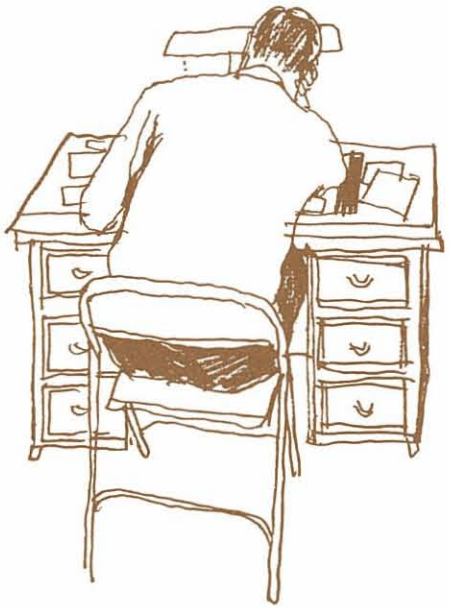
1. Chain Saw Repair is a more or less specialized business. Some retail dealers won't repair or rent chain saws. So go to the chain saw user – the contractor, tree surgeon, timber cutter, logger, city maintenance manager – and get business. If you have a special "knack" for chain saw repair, it can be very profitable.

   Repairing and sharpening chain for Chain Saws is good business, too. You can sell chain, bars, sprockets, to your customers. Of course, you will need a stock of files, a chain breaker, and a spinner for rivets. Belsaw can supply you with a good chain sharpener.

2. Nurseries use a number of tools, such as post hole diggers, tillers, tractors, etc. Offer your services to them and get business. Leave your card.

3. Golf Courses and Cemeteries. These institutions primarily use mowers and diggers. Reel mowers are a special service item and are used by many golf courses. Reel mower sharpeners are available that will handle most any mower up to 36 inches wide. If you are not interested in the sharpening of reel mowers, you can offer your services on the engines.

4. If you are in the North Country, you can service snow blowers and snowmobiles, too. The basic engine operation of the snowmobile is the same as any other two cycle engine (unless it is a rotary combustion type). There are some snowmobiles that use four cycle engines.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

EXAM FOR LESSONS 1 THRU 42

FOLEY-BELSAW INSTITUTE of SMALL ENGINE REPAIR FINAL EXAMINATION

FOLEY-BELSAW INSTITUTE OF SMALL ENGINE REPAIR
6301 EQUITABLE ROAD • BOX 593 • KANSAS CITY, MO. 64141

NAME _____ Student No. _____
PLEASE PRINT

ADDRESS _____ Date _____

CITY-STATE-ZIP _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

(3) Be sure to follow the instructions on the Homework Assignment Sheet.

ANSWER

1. The purpose of the crankcase breather on a 4-cycle engine is to allow pressure to be released and admit outside air. _____
   TRUE FALSE
2. Ring expanders are sometimes used under oil rings. _____
   TRUE FALSE
3. A cylinder with a wear taper of .035 inch would be acceptable. _____
   TRUE FALSE
4. The three basic types of starters used on most small engines are rope rewind, wind-up, and electric. _____
   TRUE FALSE
5. The _____ of oil means the resistance to the tendency to flow. _____
   A. viscosity B. compression C. continuity
6. _____ caused by a mixture of fuel and air will burn. _____
   A. combustion B. vapor C. lapping
7. Excessive pressure build-up in the crankcase of _____ engines is released through the valve access area. _____
   A. 2-cycle B. 4-cycle
8. The reference numbers in an exploded-view drawing will refer you to the part number and name.
   TRUE FALSE
9. All 2-cycle engines use oil rings. _____
   TRUE FALSE
10. During combustion, blow-by from the combustion chamber passes the piston of 4-cycle engines and goes into the _____. _____
    A. air cleaner B. muffler C. crankcase area
11. Through a gear reduction we can turn a smaller gear with little effort and create more turning force with a larger gear. _____
    TRUE FALSE
12. _____ have a resistance to the flow of current. _____
    A. insulators B. inductions C. energy
13. The presence of heat increases _____ of fuel. _____
    A. Venturi B. vaporization
14. The teeth on the crankshaft gear engage directly with the teeth on the camshaft gear on _____ engines. _____
    A. 2-cycle B. 3-cycle C. 4-cycle
15. Viscosity is the resistance to the flow of oil or fluids. _____
    TRUE FALSE
16. Fuel enters the combustion chamber through the intake valve on _____ engines. _____
    A. 2-cycle B. 3-cycle C. 4-cycle
17. Cylinders used with most small engines are generally made of cast iron or aluminum. _____
    TRUE FALSE

(Continued on page 2)

ANSWER

18. Every fuel must have some vent system to allow atmospheric pressure to equalize the pressure in the tank. _____
TRUE FALSE

19. Before removing the camshaft, you should relieve the pressure on the _____ springs. _____
A. valve B. governor C. starter

20. Two types of rod bearings used on most small engines are plain sleeve and needle. _____
TRUE FALSE

21. _____ starters used on small engines generally have a slip clutch to prevent kickback. _____
A. rope B. wind-up C. kick

22. The camshaft on 4-cycle engines opens and closes the _____. _____
A. valves B. carburetor C. breather

23. Fuel and oil pass through the carburetor on _____ engines. _____
A. 4-cycle B. 2-cycle

24. The volitility of fuel is its tendency to evaporate. _____
TRUE FALSE

25. Electricity will flow through _____. _____
A. liquids B. solids C. gases D. All of the above

26. Governors on small engines may be operated by _____. _____
A. vacuum B. air C. centrifugal force D. electrical E. all of the above

27. In working with high-voltage starting motors the extension cord should be plugged into the power source first. _____
TRUE FALSE

28. The ammeter is used to tell the operator what the generator is doing. _____
TRUE FALSE

29. The four basic types of electrical circuits are closed, open, series, and parallel. _____
TRUE FALSE

30. The relationship between the piston and the valve is controlled by the timing gear. _____
TRUE FALSE

31. The three areas of valves on a 4-cycle engine requiring the most maintenance are margin, seat, and face. _____
TRUE FALSE

32. A 2-cycle engine completes all of the actions necessary for a complete cycle during one revolution of the _____. _____
A. crankshaft B. camshaft

33. Valve overlap is a point when both valves are slightly _____. _____
A. closed B. open

34. _____ engines fire every two revolutions of the crankshaft. _____
A. 2-cycle B. 4-cycle

35. Valve lifters on 4-cycle engines work directly off the lobes of the camshaft on most small engines. _____
TRUE FALSE

36. A _____ is used to check the specific gravity of the electrolites. _____
A. hydrometer B. regulator C. volt meter

37. A regulator is used to prevent the battery from receiving an excess charge. _____
TRUE FALSE

38. Direct current flows from positive to negative. _____
TRUE FALSE

39. A _____ is a device used to convert chemical energy into electrical energy. _____
A. coil B. condenser C. battery

40. Ampere is the unit of measurement for the flow of current. _____
TRUE FALSE

41. The change of direction of _____ current is known as a cycle. _____
A. direct B. alternating

42. A rectifier is used to change _____ current to _____. _____
A. alternating to direct B. direct to alternating C. either of the above

(Continued on page 3)

ANSWER

43. Direct current starters are operated from a battery. ___
TRUE FALSE

44. A _____ prevents the generator from overwork. _____
A. regulator B. condenser C. distributor

45. Generator brushes are usually made of a _____ material. _____
A. aluminum B. iron C. carbon

46. Volts are the unit of measurement for the force of current. _____
TRUE FALSE

47. A battery is recharged by reversing its _____ action. _____
A. chemical B. mechanical

48. When the piston of a 4-cycle engine is on the intake stroke, it is on the way _____. _____
A. up B. down C. either of the above

49. A 4-cycle valve assembly consists of _____. _____
A. valves, springs, retainers B. piston, rings, skirt C. breather, crankcase, carburetor

50. Valve tappet clearance is the distance between the valves and lifters. ___
TRUE FALSE

51. Tappet clearance is necessary because valve stems _____. _____
A. contract B. expand C. neither of the above

52. Valve timing marks for most 4-cycle small engines will generally be located on the camshaft and the _____. _____
A. rod B. crankcase breather C. crankshaft

53. When the valve lifter is riding on the high point of the cam, tappet clearance should be at the maximum. _____
TRUE FALSE

54. When the piston of a 2-cycle engine is traveling up, it creates a vacuum or low-pressure area in the crankcase. ___
TRUE FALSE

55. _____ is the point where the piston reaches the top of the compression stroke. _____
A. bottom dead center B. top dead center C. can be either of the above

56. If a magneto has adequate voltage to jump a _____ gap, it should ignite the spark plug. _____
A. 1/8″ B. 5/8″ C. 7/8″

57. The breaker points of the ignition are timed to open at the instant the magnetic field reaches its maximum strength. _____
TRUE FALSE

58. The three basic types of ignition systems used on small engines are battery, magneto, and solid state. _____
TRUE FALSE

59. In a magneto ignition system the switch is always open when the engine is running. ___
TRUE FALSE

60. Every up stroke on a _____ engine is a compression stroke. _____
A. 2-cycle B. 4-cycle

61. The contact points must be timed to the rotation of the crankshaft. ___
TRUE FALSE

62. The primary purpose of the _____ is to absorb excess current and to keep the breaker points from arcing. _____
A. alternator B. rectifier C. condenser

63. In a battery ignition system the switch is always closed when the engine is running. _____
TRUE FALSE

64. A faulty condenser can cause the points to _____. _____
A. burn B. pit C. both of the above

65. Fuel with an octane rating that is too low can cause detonation. _____
TRUE FALSE

66. A ridge around the top of the cylinder would indicate that both the cylinder and the _____ were worn. _____
A. rod B. piston C. crankcase

(Continued on page 4)

ANSWER

67. After the valve face and _____ are ground, it is necessary to remove some metal from the stem. _____
A. seat B. points C. neck

68. Valve burning will often be caused from a sticky valve stem not running free in the guide. _____
TRUE FALSE

69. If the valves and valve seat areas show only slight wear, they can usually be _____ to bring them back to good condition. _____
A. ground B. filed C. lapped

70. Current is flowing through the condenser when the contact points are closed. _____
TRUE FALSE

71. The armature air gap is the distance between the laminated iron cores and the magnets. _____
TRUE FALSE

72. The high tension wire carries voltage from the magneto to the _____. _____
A. spark plug B. condenser C. points

73. The breaker point spring holds the points _____. _____
A. open B. closed

74. If the points are set too close they will retard or slow the timing. _____
TRUE FALSE

75. A _____ is rated in units called microfarads. _____
A. contact points B. rectifier C. condenser

76. Intake valves generally begin to show wear first. _____
TRUE FALSE

77. Detonation occurs when fuel burns unevenly. _____
TRUE FALSE

78. In order to get a tight seal it is necessary to grind the valve margin each time the engine is worked on. _____
TRUE FALSE

79. Two-cycle engines use a dipper or scoop method to distribute oil inside of the crankcase. _____
TRUE FALSE

80. If the margin of the valve is less than _____, it should be replaced. _____
A. 7/8" B. 9/16" C. 1/64"

81. Evidence of gum and varnish deposits around the intake valve area indicates the use of low quality fuel. _____
TRUE FALSE

82. A ridge around the top of the cylinder wall will require the use of a ridge reamer before the _____ can be removed. _____
A. piston B. carburetor C. head

83. Valve tappet clearance is checked with a feeler gauge. _____
TRUE FALSE

84. After valves have been ground several times the margin increases in width. _____

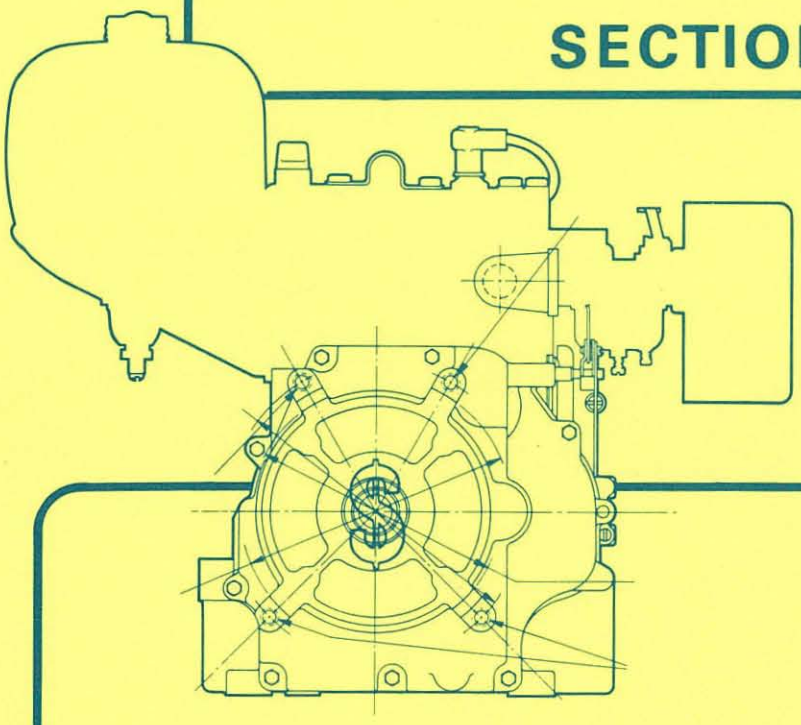
TRUE FALSE

Small Engine

Repair & Service

ADVANCED TRAINING

SECTION I



TURN THIS PAGE

...and let's find out all about --

POWER MOWER REPAIR

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POWER MOWER REPAIR

Table Of Contents

1 Power Mowers
1 Parts of the Rotary Mower
3 Blade Tracking
5 Blade Stiffeners
6 Rotary Blade Sharpening
10 Rotary Blade Balancing
12 Piston and Blade Alignment
13 Rotary Wheel Adjustment
14 Throttle Control Adjustment
15 Exhaust Port Cleaning
16 Self-Propelled Upper Belt Drive
17 Self-Propelled Lower Belt Drive
18 Right Angle Drives
19 Forward-Reverse Bevel Gears
20 Transmissions
23 Clutches

POWER MOWERS

The beginning of mechanical mowers started in England about 1830. They consisted of a reel blade and cutting bar similar to the push type reel mowers used only a few years back. These early mowers were either propelled by pushing or drawn by horses. It wasn't until about 1900 that the first gasoline engine powered mower was introduced. Just a few years later, about 1920, the electric power mower was introduced. These were driven with electric motors to drive the reel and sometimes the wheels of the reel mower. By the year 1924 there were almost one million hand-push reel mowers sold in the U.S. About this same time, the reel type mower powered with either electric or gasoline engines were beginning to take over the mower market.

Up until this time mowing machines were all reel type. About 1935 the rotary power mower was introduced. This was the first time that a horizontally-mounted cutting blade began to appear on the American market. The rotary mower became instantly popular in this country and within a very few years it had captured over 90% of the power mower market.

PARTS OF THE ROTARY MOWER

Rotary mowers are generally designed with four wheels to support a housing. A vertical crankshaft engine is attached to the housing and a horizontal mounted cutting blade is attached to the crankshaft inside and beneath the housing.

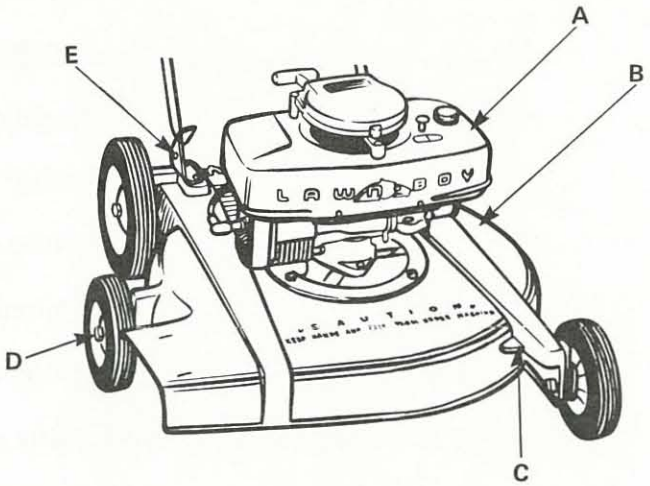


Figure 1

Figure 1 shows the basic parts of a typical rotary power mower. The engine, shown at A, is a vertical crankshaft engine generally from 2 to 5 horsepower. The most common is 3 or 3-1/2 H.P. These can be either 2-cycle or 4-cycle engines.

The housing shown at B is generally made of aluminum, magnesium or light gauge steel. Each of the four wheels are adjustable for height some place in the area shown at C. Different makes have different methods of making wheel adjustments. We'll cover this in more detail later.

The wheel and axle shown at D is generally held to the housing by one bolt and bearing. Notice the wheels are staggered around the mower housing. This is to prevent the housing and blade from dropping down on uneven ground. The handle attachment shown at E is adjustable for height and convenient removal.

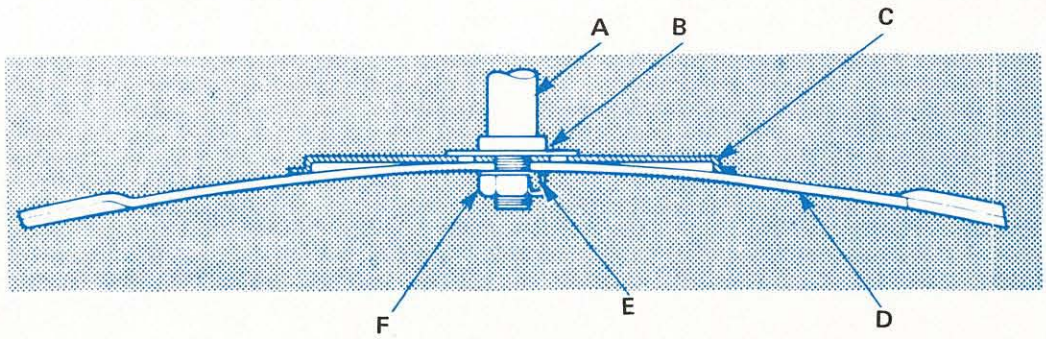


Figure 2

The blade and attachments shown in Figure 2 are not simply a piece of sharpened steel attached to an engine shaft for cutting. The cutting action of a rotary mower is designed to lift the grass, cut it smooth and discharge the grass out the side of the mower housing. An improperly designed or maintained blade or blade assembly will not perform these three actions properly.

The blade assembly is attached direct to the engine shaft shown at A. There is a shaft collar and clutch plate shown at B and the blade at D. The purpose of the clutch plate is to provide some method of slipping in case the blade hits some solid object. The clutch plate is generally made of some fiber or non-metallic material that will allow the blade to slip on the shaft without grinding two pieces of metal together.

Without a clutch, or some method of allowing for a cushion, shock would be transmitted directly to the crankshaft in case the blade hit some foreign object. Operating a mower without slip clutch or one too badly worn will transmit the shock load direct to the crankshaft and generally damage it. This can cause a very costly repair job since the entire engine crankshaft will have to be replaced.

The part shown at C is the blade stiffener and keeps the blade cutting in a constant plane. In order for a blade to develop the life necessary to raise the grass, it must have some curved shape rather than be flat. Centrifugal force tends to force the blade out flat. The purpose of the blade stiffener is to keep the blade in this curved position.

Most mowers will have a lock tab, shown at E. After the blade holding nut, shown at F, has been tightened, one ear of the lock tab is bent down over the shoulder of the nut to keep it from working loose. Generally these lock tabs have several ears and can be used more than one time. The ears will usually break off after they have been bent back for loosening the nut.

These are the basic parts of most rotary mowers. Different makes and models will have slightly different engineering designs but the general principles will be similar.

BLADE TRACKING

Blade tracking actually means the angle at which the blade travels across the lawn. Improper blade tracking can be caused from a warped housing, individual wheels not set at the same cutting height, bent blade or blade stiffener or blade out of balance.

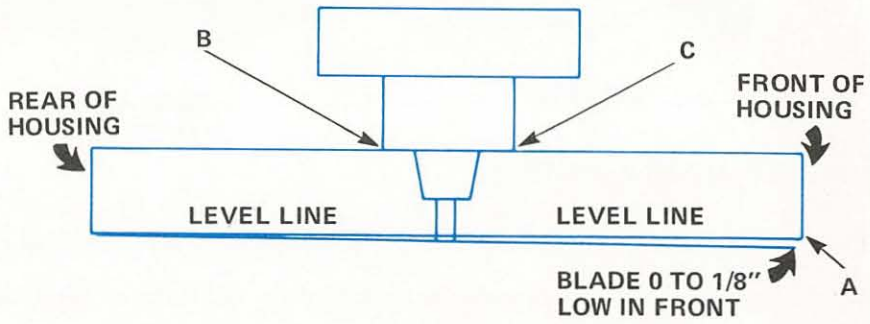


Figure 3

If the blade does not track properly it will cause a swirl, arc, or half moon cuts on smooth level lawns.

For best cutting, the blade should be aligned to cut as shown in Figure 3. The front part of the blade shown at A should be from 0 to 1/8 inch low or down from a level line. Adjustments can be made to correct the tracking by adding thin shims between the engine and the housing at the points shown at B and C. By adding a shim at either of these points you can raise or lower the front of the blade.

Now, let's look at a top view of this blade and housing, as shown in Figure 4. If the front shown at A is 0 to 1/8 inch low, the back side shown at B can be 0 to 1/8 inch high. The sides shown at C and D may be 0 to 1/8 inch high or low but preferably as near level as possible.

To check the blade track place the mower on a flat surface with all wheels set at the same height. Measure the distance between the tip of one end of the blade in four different positions 90 degrees apart, front, side, rear and side.

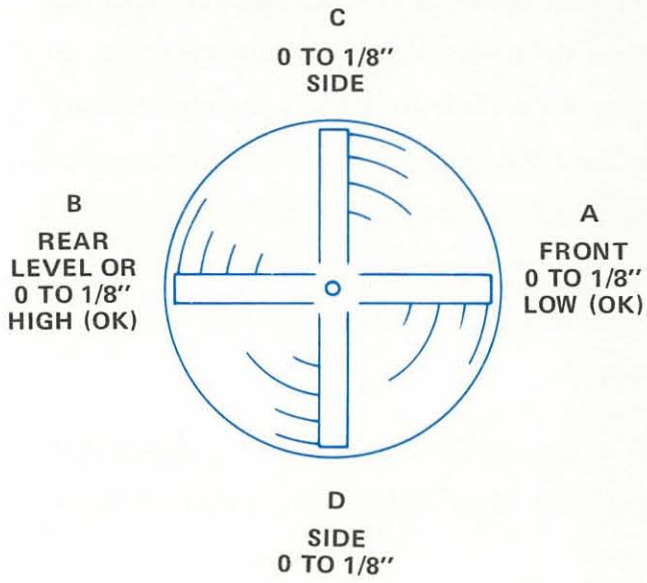


Figure 4

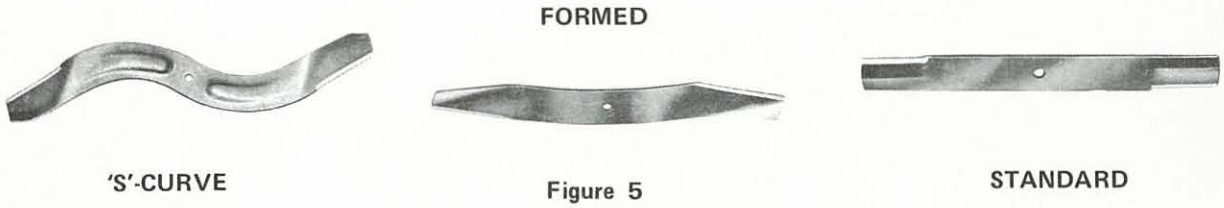


Figure 5

ROTARY MOWER BLADES

Figure 5 shows the three basic styles of cutting blades used on most rotary mowers. Most mowers will have one of these blade designs or some variation of it. All three of these designs will have to be serviced properly to insure proper cutting action.

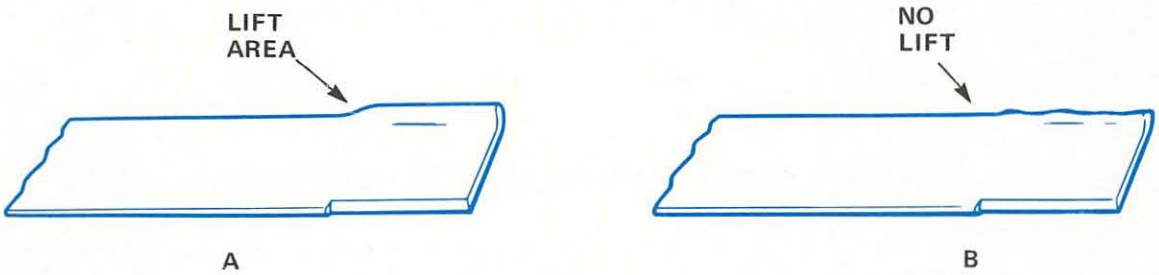
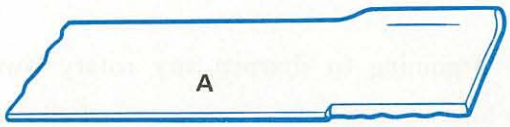


Figure 6

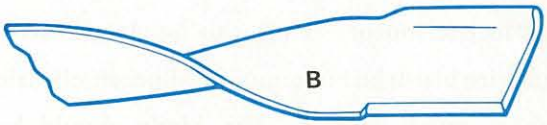
Figure 6 shows the lift area of a rotary blade. This is the raised area on the back side of the cutting edge. With all other conditions good, this blade should do a satisfactory job of cutting. The blade shown at B does not have enough lift on the back side. It will not cut grass evenly and will not discharge the grass properly.

Figure 7 shows two blades in bad condition. The one at A is dull and will cause ragged cutting. A dull blade will also consume much more power than necessary and throw an unnecessary strain on the engine. The blade shown at B is twisted and will make a very ragged cut. It will cause excess air currents that can cause inefficient grass discharge.

Always replace or repair a blade that is questionable as they can cause damage to the engine and injury to the operator.

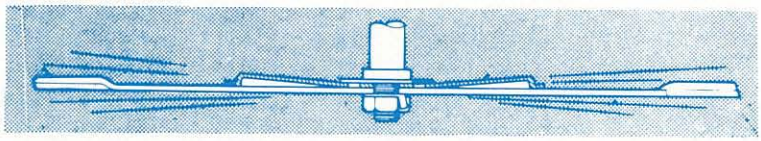


DULL BLADE

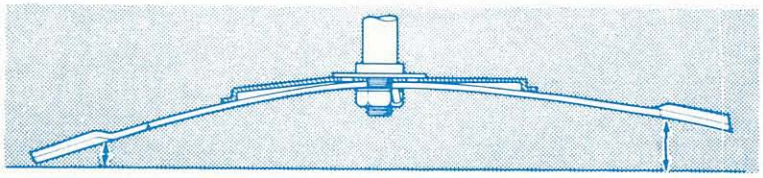


TWISTED BLADE

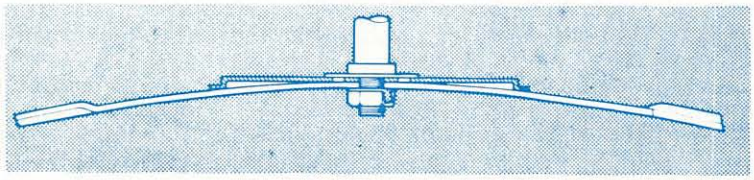
Figure 7



A



B



C

Figure 8

BLADE STIFFENERS

Blade stiffeners are a very important part of any blade assembly. Figure 8 shows three conditions that are caused directly by the blade stiffener. The blade shown at A has a weak stiffener. Engine speed and centrifugal force will cause the cutting tips of the blade to move up and down and flutter. This produces a very uneven and ragged cutting action in addition to damaging the crankshaft and engine bearings.

The stiffener shown at B is bent and will cause an uneven tension on the blade. One side of the blade will be bent down more than the other causing the blade to cut low on one side and high on the other. This will also cause uneven cutting and throw excess strain on the crankshaft and engine bearings.

A good stiffener as shown at C, holds the blade evenly on both sides, permitting the blade to cut in a true plane.

ROTARY BLADE SHARPENING

Before beginning to sharpen any rotary lawnmower blade it should first be cleaned of all rust, gum and dirt. The best way to do this is with a rotary wire brush mounted on a bench grinder or other electric motor. They can be cleaned with a hand wire brush but one mounted on an electric motor is much faster. The blade should be cleaned down to the bare metal. Any build up of foreign material on the blade will cause it to be out of balance.

After the blade is cleaned, it should be inspected for cracks, breaks or distortion. Very small cracks that are hard to see may be present in a blade. With the blade suspended in the air, tap it with a metal object several times. If the blade is solid it will ring like a bell. If there is a dull thud, there is a crack or other structural fault and it will have to be replaced.

The cutting angle of the rotary blade is very important. The cutting angle must cut the grass clean. Cutting angles will sometimes vary from 20 to 25 degrees, depending on the specific use and application.

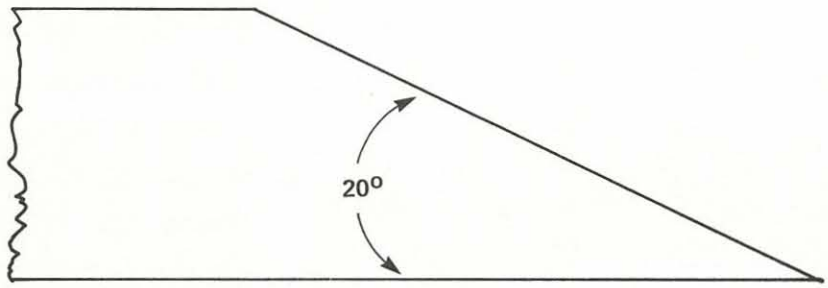


Figure 9

Figure 9 shows a typical blade with a cutting angle of 20 degrees. A blade sharpened at this angle will consume very little power compared to a larger angle. It will cut very clean but will be limited to a very short life between sharpenings. The thin edge will be easily damaged by any foreign object or tough material. This angle would be satisfactory for a smooth lawn free of any foreign objects or tough cutting. It will slice clean, leaving a minimal amount of damage to the grass.

A dull blade doesn't cut grass, it tears it apart, which is damaging to the grass. Golf greens require a very smooth cut with a sharp blade and would use one sharpened at about 20 degrees as shown in Figure 9. This would not be recommended for the average lawn.

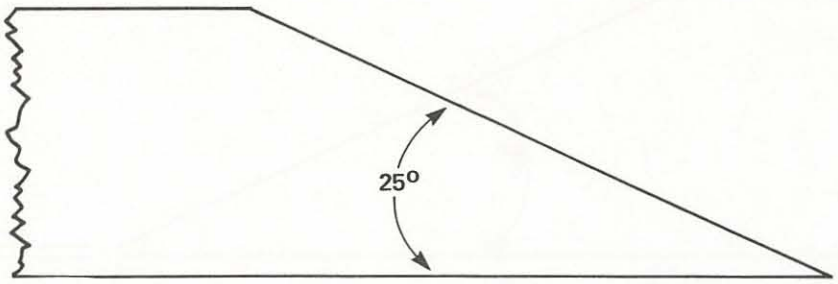


Figure 10

Figure 10 shows a blade sharpened at a 25 degree angle. This is recommended for average lawn cutting. It will not cut as smooth as the one shown in Figure 9 and will consume a little more power. It will not dull as quickly, and will cut considerably longer between sharpenings due to the more blunt angle.

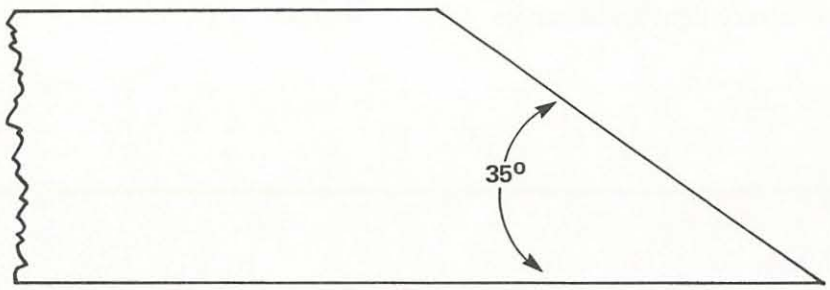


Figure 11

Figure 11 shows a blade sharpened at a 35 degree angle. This will consume more power, cut rougher and operate longer between sharpenings. If the mower is being used primarily for rough cutting, such as weeds and other rough usage, this cutting angle would be satisfactory.

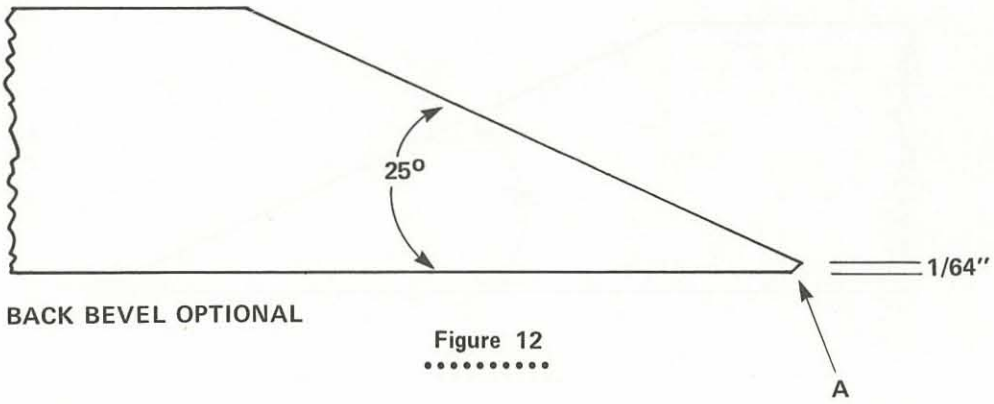


Figure 12

Another sharpening angle is shown in Figure 12. This is known as the back bevel or "heel". This is probably the most popular sharpening angle for the average home lawnmower.

The extreme cutting angle shown in Figure 9 will have a tendency to roll over on the edge. After sharpening at the proper angle, the blade can be turned over and a very light grind can be made on the back side as shown at A. Leave about 1/64 inch flat as shown.

This type sharpening relieves the burr that will occur when grinding and also relieves the extreme cutting angle, making the cutting edge last longer between sharpenings. The blade will also become sharper after use. The wear point of the cutting edge is at the flat part of the blade at A. As this wears, the cutting angle will become sharper.

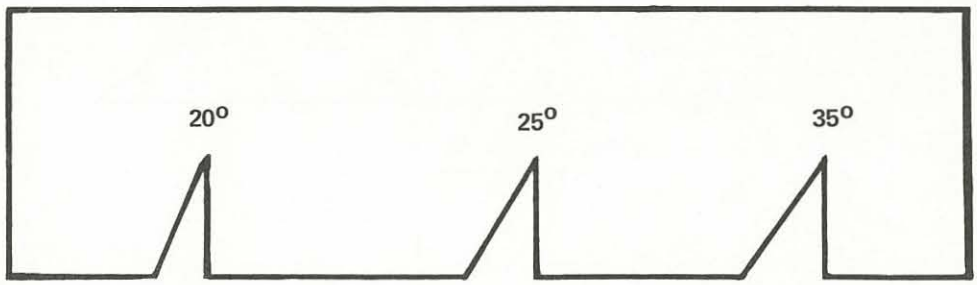


Figure 13

A template as shown in Figure 13 can easily be made from a piece of thin metal. This will allow you to check the blade for the proper cutting angle without guessing.

Single blade direct drive rotary lawnmowers turn clockwise. Looking down through the top of the engine and mower housing, the engine shaft of both 2-cycle and 4-cycle engines turn clockwise.

Some larger commercial mowers are belt driven and may drive more than one blade. They may turn either clockwise or counter clockwise. The blades are sharpened differently as shown in Figure 14. The blade shown at B is the type used with single blade mowers. It turns clockwise looking down from the top. Some belt driven mowers and ones using more than one blade may operate counter clockwise as shown at A. Sharpening angles would be the same, except they would be on opposite sides of the blade.

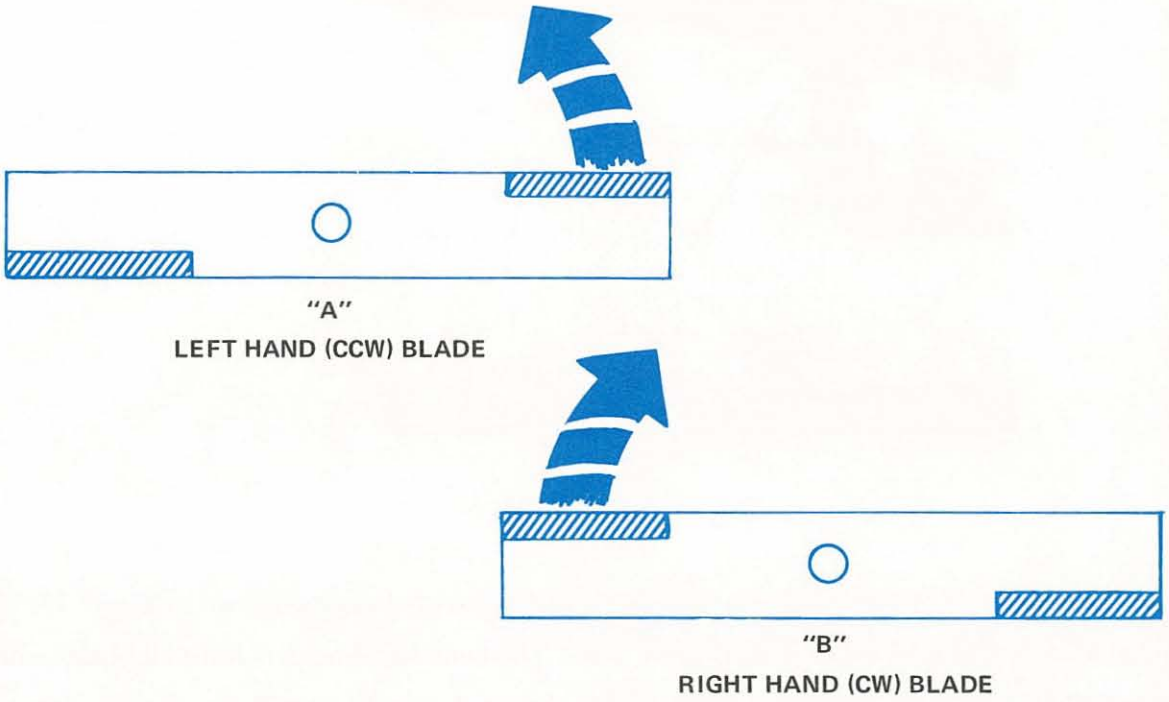


Figure 14

Care must be taken in sharpening rotary mower blades not to generate too much heat. Grinding blades creates a considerable amount of heat and will cause the blade to lose it's temper and become soft. Dip the blade in water often to cool it.

CAUTION: Never stand directly in front of any grinding operation. There is danger of injury from flying particles. Always wear eye and face protective devices when doing any grinding. Check condition of grinding wheels or belts.

ROTARY BLADE BALANCING

In addition to being sharp a rotary blade must be balanced. At an engine speed of around 3000 RPM an out of balance blade can create considerable vibration, which is harmful to the engine parts, along with being dangerous.

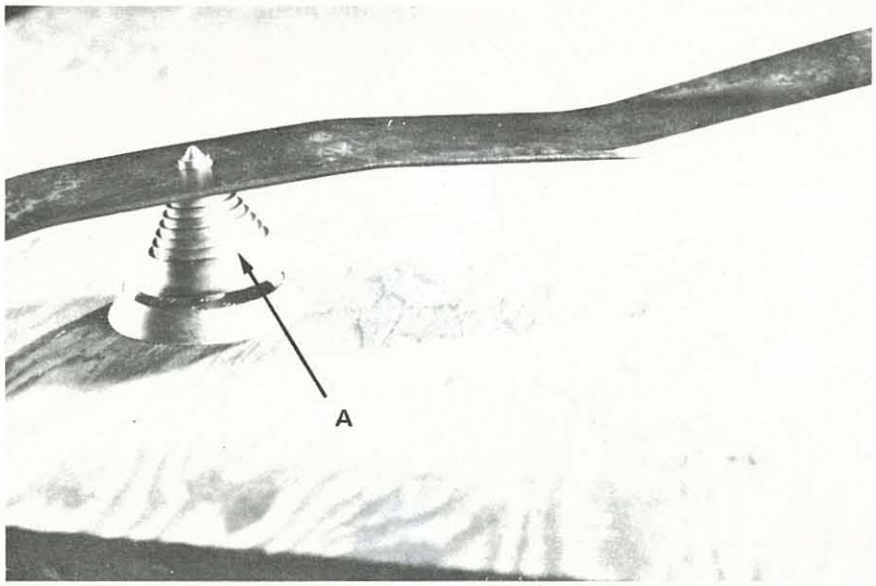


Figure 15

One of the best methods of balancing rotary blades is with a cone balancer as shown in Figure 15. The step cone shown at A is balanced on a pointed pivot post. The cone has shoulders to fit all blades with center holes from 3/8 to 1-1/2 inch diameter. If the blade is heavy on one side it will drop down on that side. It will then be necessary to remove more metal from that side until the blade balances level on the cone.

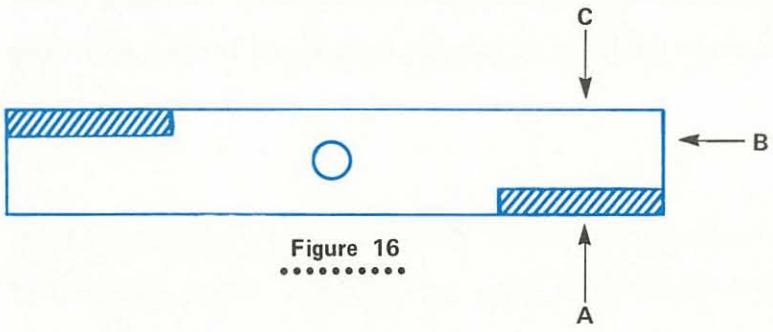


Figure 16

To balance the blade metal can be removed from the cutting edge on the heavy side and from the end of the blade as shown in Figure 16. If a small amount of grinding at A will balance the blade, remove the metal from this point. Some metal can also be removed from point B at the end of the blade. Never grind on the back side of the blade at C as this will destroy the lift.

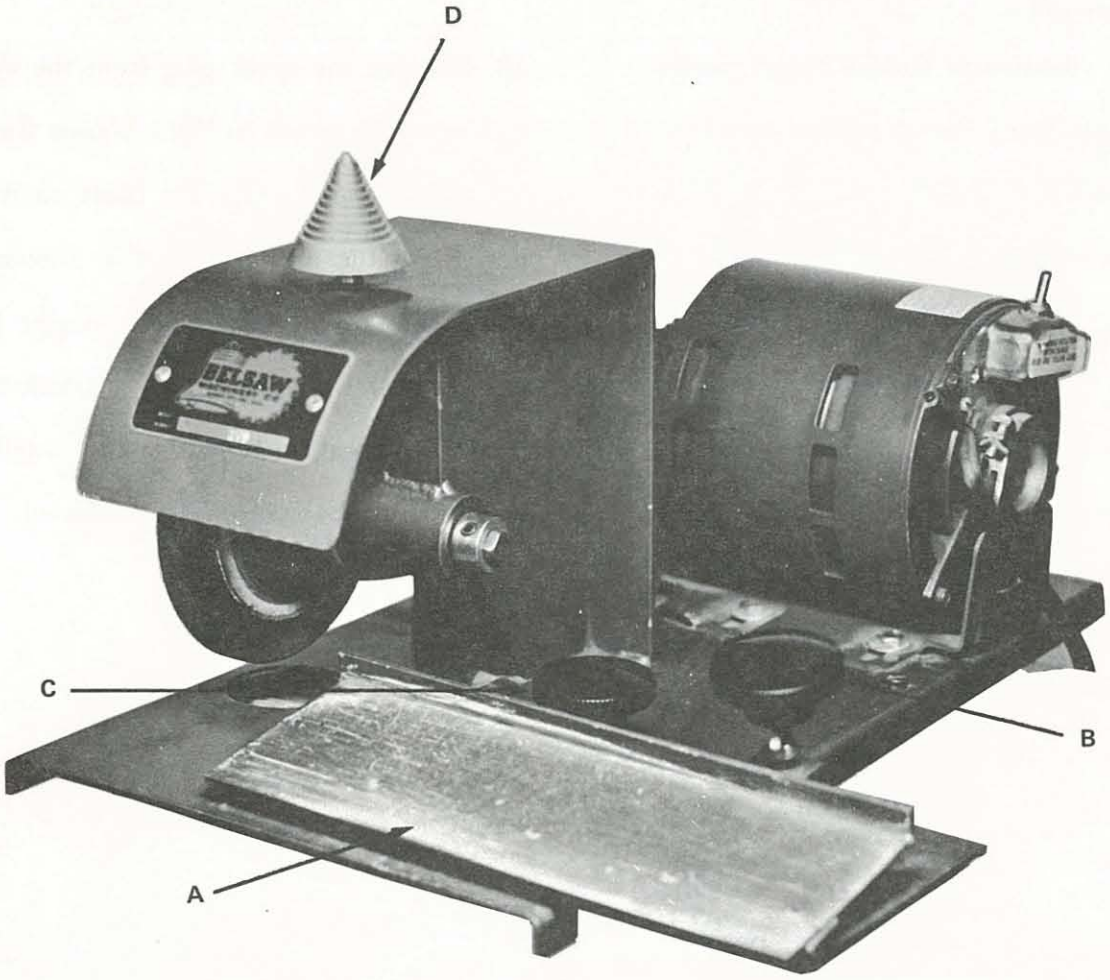


Figure 17

Figure 17 shows the Belsaw Model 279 Rotary Mower Blade Sharpener and Balancer. This machine will do a complete sharpening and balancing job on all three basic styles of rotary mower blades. The blade guide assembly shown at A is adjustable to get the proper grinding angle on the blade. The control knob shown at B raises and lowers the table of the guide assembly to the proper grinding angle. It is then locked in place. The guide assembly can be moved toward or away from the grinding wheel and locked in place with the control knob shown at C. This assures the proper grinding depth and angle for each edge of the blade. In addition to sharpening, the blade can be balanced on the built in balancer shown at D.

PISTON AND BLADE ALIGNMENT

Lawnmower vibration is almost always caused from the blade being out of balance or a bent engine crankshaft. Sometimes vibration will be present even though both of these conditions are correct. A mower will sometimes run smoother, if the blade is aligned at right angles to the piston and rod assembly, when the piston is at top dead center (TDC) as shown in Figure 18. Remove the spark plug from the cylinder and bring the piston to TDC. Loosen the blade holding nut and rotate the blade so it is 90 degrees to the piston and rod as shown at A. Install the blade and test the engine in this condition. If vibration is reduced, mark the end of the crankshaft at B so it can be installed the same way when the blade is resharpened.

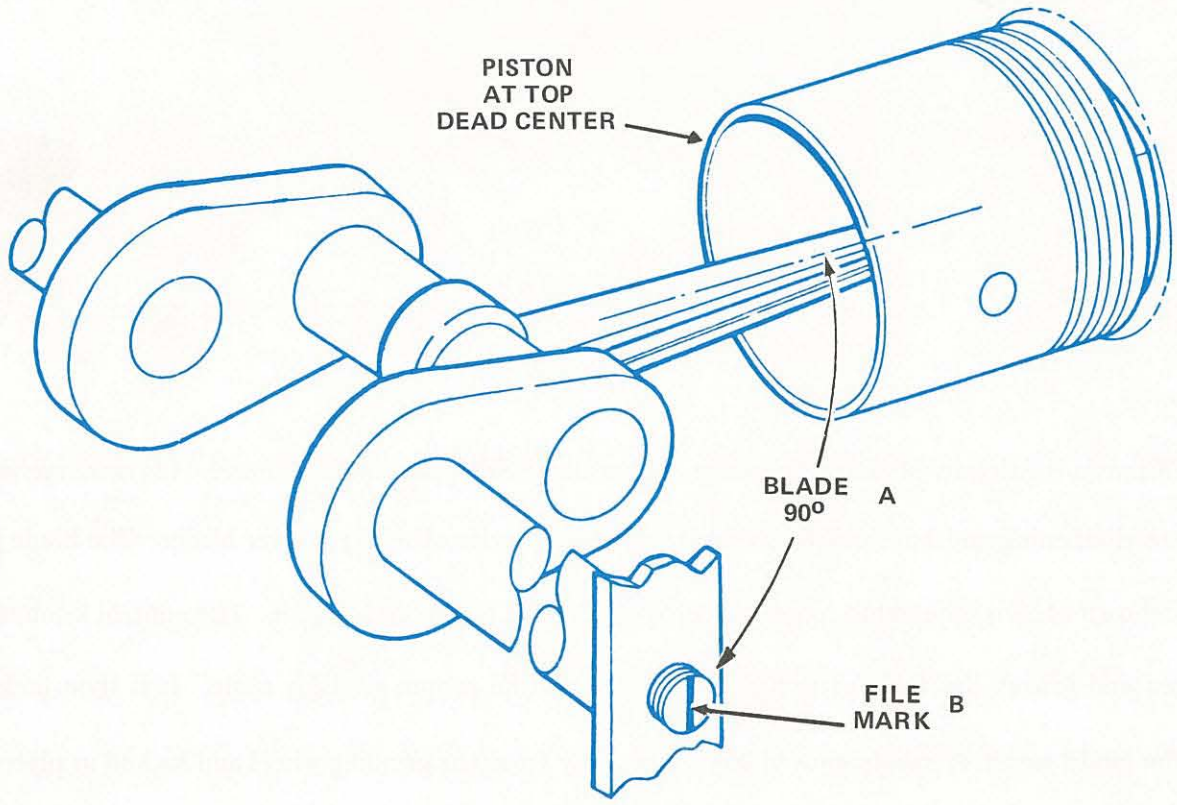


Figure 18

ROTARY WHEEL ADJUSTMENT

The basic purpose of adjustable wheels on rotary mowers is to raise or lower the height of the base and cutting blade. Generally each wheel is adjustable independently. Most mower bases are made of very light material and can be easily damaged by subjecting them to unnecessary strain. All four wheels must be adjusted to the same height in order for the housing to be supported equally at four points.

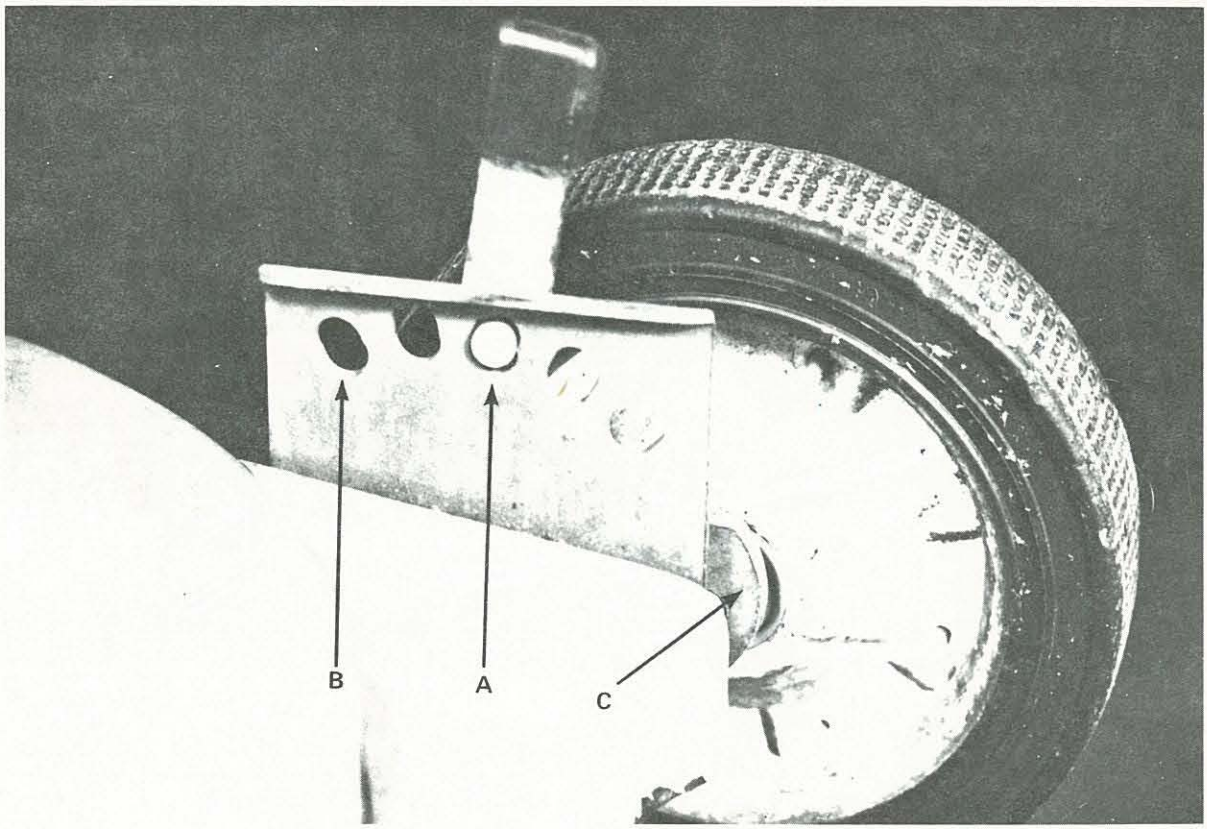


Figure 19

Figure 19 shows a typical wheel adjustment design. There are many variations of this design but they all serve the same function. If the control adjustment is moved to the hole shown at A, it will raise the wheel up. This lowers the housing and blade. If the control adjustment is moved to the hole shown at B the wheel will be lowered and the housing raised for higher cutting.

All four wheels are adjustable and it is very important to have them adjusted the same. If any one wheel is not adjusted the same as the other three, the weight will not be evenly distributed and will cause strain on the housing which would eventually cause it to break. Always inspect the condition of the wheel and axle bearings located at C when servicing mowers. Lubricate or repair as necessary.

THROTTLE CONTROL ADJUSTMENT

Often the wrong adjustments are made when adjusting linkages. There are three basic parts to most linkage controls as shown in Figure 20. The stationary anchoring points are shown at A and B. These are locked in place and hold each end of the cable housing shown at C, a fixed distance apart.

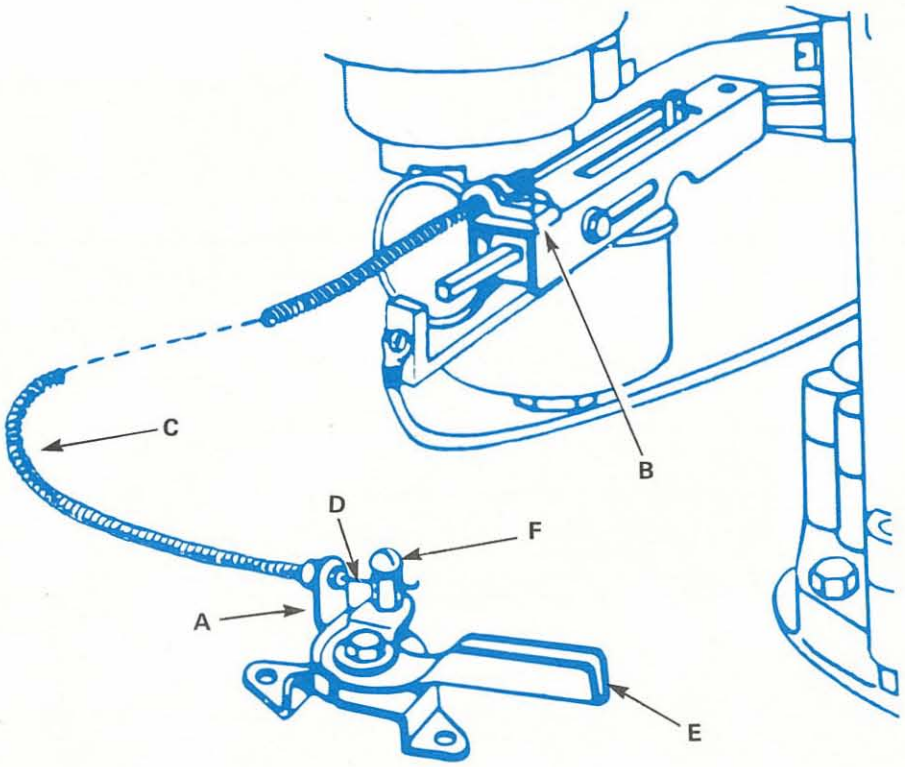


Figure 20

The control cable shown at D moves back and forth inside the cable housing when the handle E is moved. To increase or decrease the amount of travel of the control cable, loosen the screw shown at F and move the handle E left or right and relock the screw. Sometimes mechanics will attempt making this adjustment by adjusting the outside cable housing at point B. This will change the control setting but is a very difficult adjustment and not as sensitive as making the adjustment at point F.

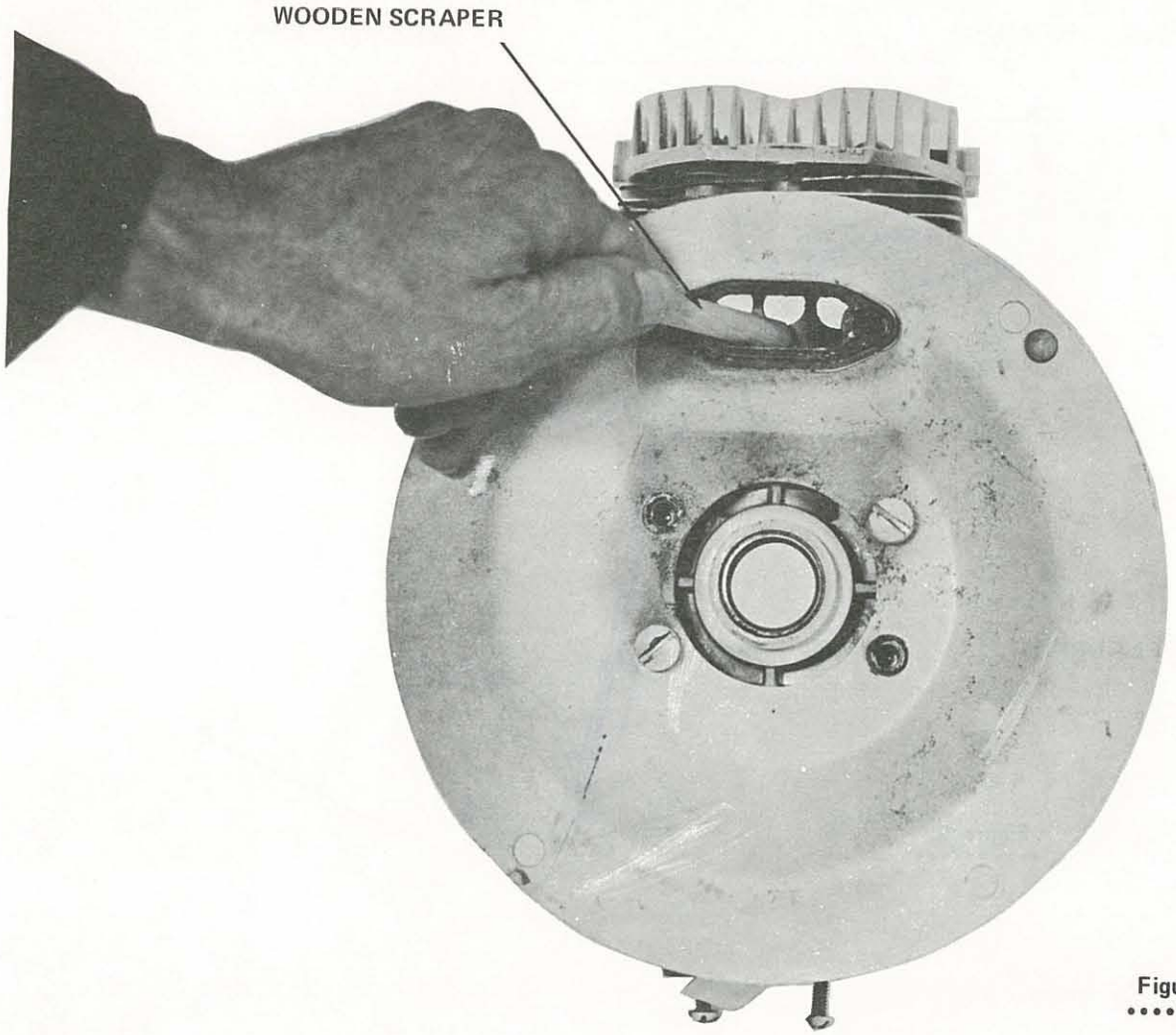


Figure 21

EXHAUST PORT CLEANING

Loss of engine power can often be caused by restricted exhaust ports on 2-cycle engines. This restriction results from a build up of carbon deposits and should be checked and cleaned each time the engine is serviced. If carbon deposits are allowed to build up in the exhaust port area of 2-cycle engines, there is danger of pieces of it breaking away and falling into the power head. If these deposits are allowed to get into the power head they will damage the piston and cylinder wall.

To get at the exhaust ports, first remove the muffler. On lawnmower engines the muffler is generally located inside the mower base. After the muffler has been removed check the exhaust ports for carbonizing. Turn the crankshaft so the piston is just covering the exhaust ports. This will prevent carbon from entering the cylinder area. Use a wooden scraper as shown in Figure 21. After the exhaust ports have been cleaned, inspect the gasket and replace the muffler.

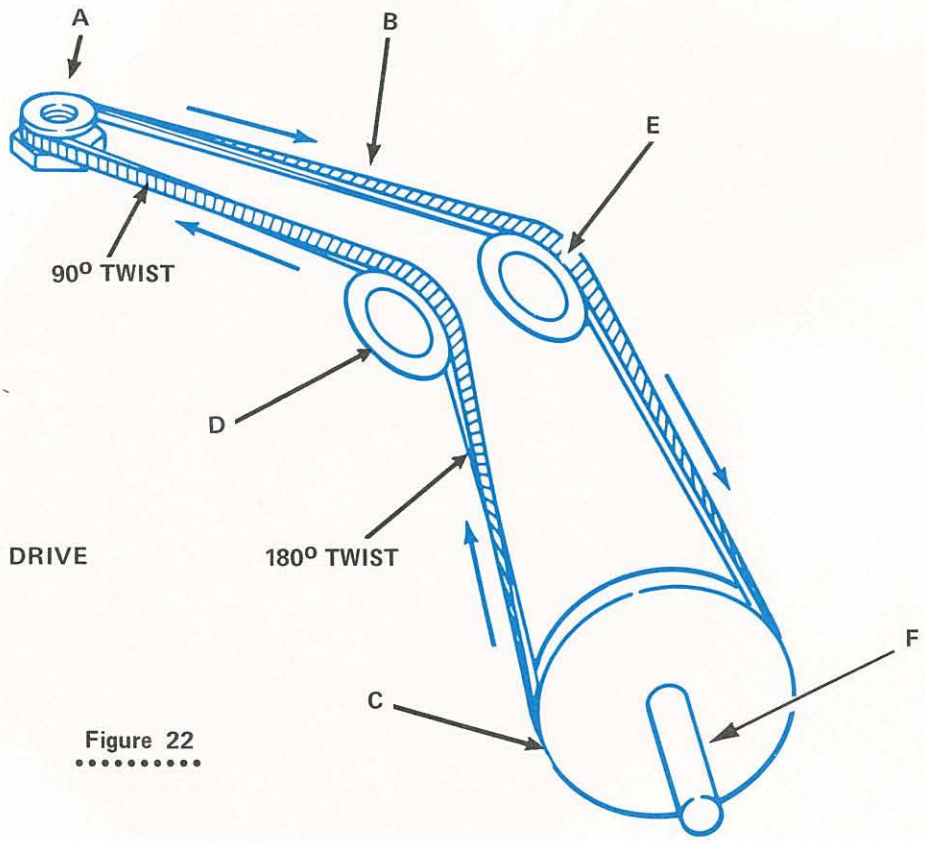


Figure 22

SELF-PROPELLED UPPER BELT DRIVE

The basic theory of the upper belt drive is shown in Figure 22. The drive pulley shown at A is attached to the top part of the engine shaft outside the mower housing. Since this is a vertical shaft engine it is necessary to use a twist belt as shown at B to drive the lower horizontal pulley on shaft C. The horizontal shaft in turn drives both rear wheels of the mower. In order to change the direction of the belt from horizontal to vertical the stationary pulley shown at D is used and the idler pulley shown at E.

The idler pulley is adjustable for belt tension. The drive shaft shown at F has a drive roller attached to each end, that engages the rear wheels of the mower. The drive shaft F is turning all the time the engine is running. When this shaft and drive roller engage the rear wheels the mower moves forward.

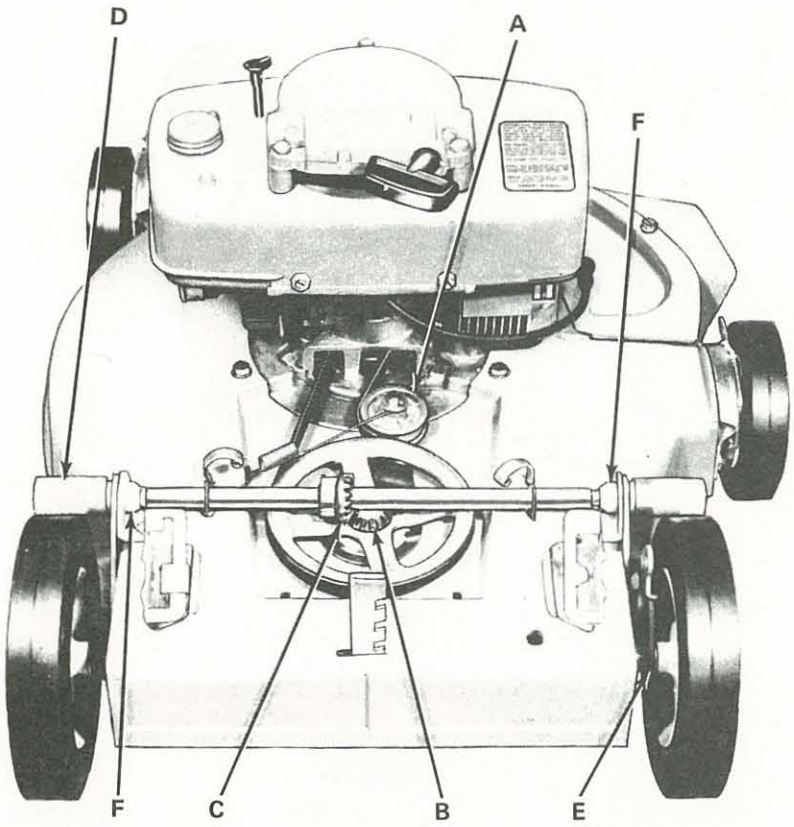


Figure 23

SELF-PROPELLED LOWER BELT DRIVE

Another type of belt drive is powered from the lower end of the engine shaft as shown in Figure 23. A pulley on the lower engine shaft drives the larger pulley. This belt is kept tight by the spring tension on the idler pulley shown at A. The larger driven pulley has a bevel gear attached to it as shown at B. This bevel gear matches and turns the other bevel gear shown at C which drives the horizontal shaft. The drive rollers D turn both rear wheels.

This driving mechanism is a little different than the upper belt drive in that the wheel moves to the drive roller to propel it forward. On the upper drive unit the drive roller moves to contact the wheel.

The clutch linkage shown at E is controlled from the handle. When engaged, it moves the wheel just enough to contact the drive roller to turn the wheels. The points shown at F are grease overflow points. When the drive rollers are lubricated grease will begin to come out this area when it is full.

RIGHT ANGLE DRIVES

In some more expensive drive units, gears are used to transmit power for applications similar to the belt drive units we have just covered. The basic principle of the bevel gear drive unit is to transmit power from one angle to another. These are sometimes called miter gears. Figure 24 shows an exploded view drawing of the basic parts of the right angle drive.

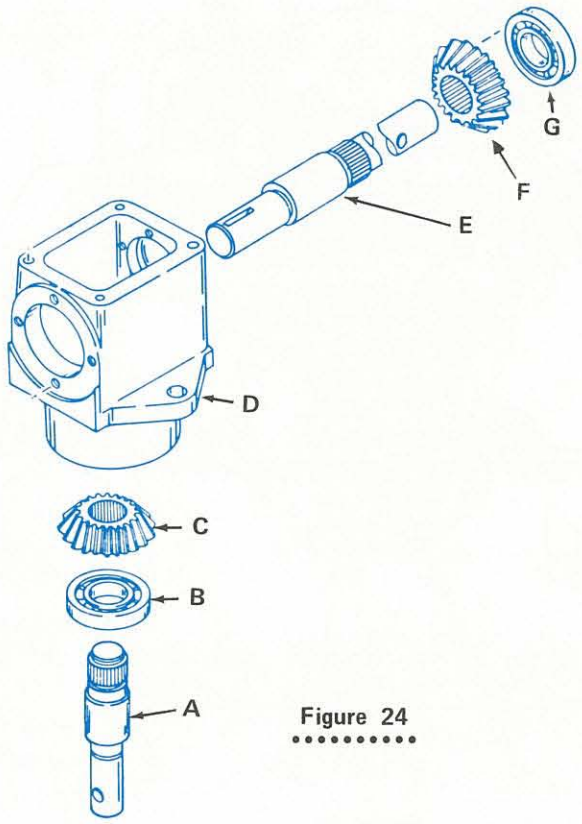


Figure 24

The power input shaft is shown at A and the bearing at B. The bevel gear shown at C is attached to the input shaft with a key. This assembly fits into the housing D.

The output shaft E can either extend out one side of the housing or it can go all the way through and extend out both sides of the housing. This would permit transmitting power to the driven shaft at two different points. The bevel gear for the output shaft is shown at F and the bearing at G. These are the basic parts of the right angle or "T" drive. Most engines transmitting power to the driving wheels of a rotary lawn-mower will use a gear or belt drive operating on these principles.

FORWARD-REVERSE BEVEL GEARS

Most gear drives used with small engines operate on a very simple principle. Earlier when we studied the timing gears used in 4-cycle engines we covered how gears reverse. The driven gear always turns opposite to the driving gear. These were straight cut teeth gears. The bevel gear is made considerably different but in effect it has a similar relationship.

Figure 25 shows three gears all in the neutral position. The drive shaft is shown at A and the bearing at B. The drive shaft is connected direct to the engine or clutch. The gear shown at C is held on this shaft with a key and turns with the shaft. In this condition the engine could be driving shaft A and turning gear C, but the two gears and shafts shown at D and E would not be turning because they are not engaged with the drive gear. As long as the gears are in this position no power is transmitted to the driving axles.

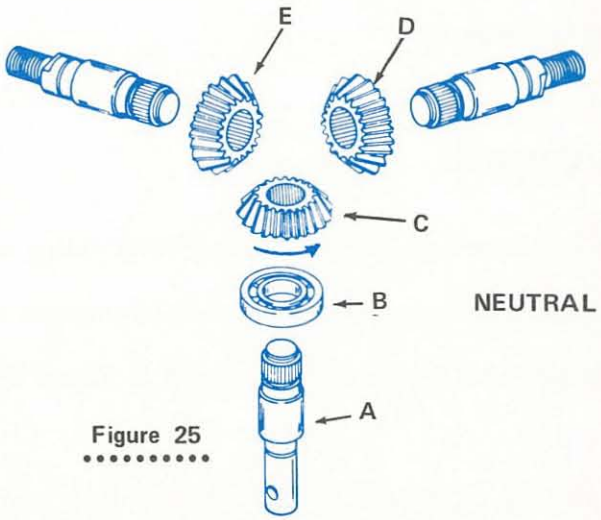


Figure 25

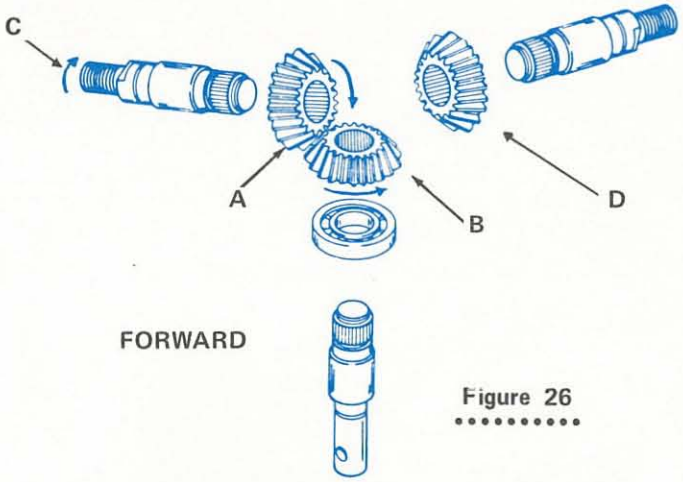
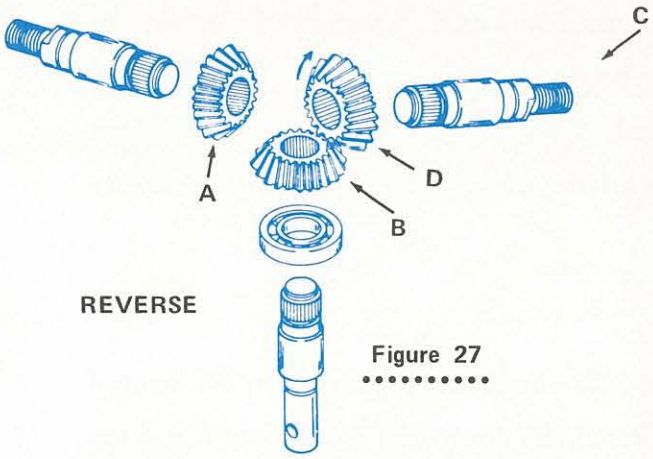


Figure 26

Figure 26 shows two of the gears engaged. Gear A has moved over and is engaged with the driving gear shown at B. The driven shaft is now turning in the direction of the arrow shown at C. This could be the position of the gears for forward movement. As long as these two gears are meshed, they will be turning in the direction shown. Gear D will not be turning.

Figure 27 shows the gears in the reverse condition. Gear A has moved back out of mesh with the driving gear B. Gear D has moved in to engage drive gear B. The drive shaft is now turning in the direction of the arrow shown at C. This is in the opposite direction as the shaft was turning in Figure 26.



REVERSE

Figure 27

TRANSMISSIONS

Transmissions are generally used only with riding equipment using 5 H.P. or more. So that you will be familiar with the general principles of transmission design we will cover some of the basic principles of a simple two speed transmission as shown in Figure 28.

This exploded view drawing shows only the basic parts necessary to change from one speed to another. The gear housings shown at A contain the entire driving mechanism. They are sealed together and all parts are operating in a heavy lubrication.

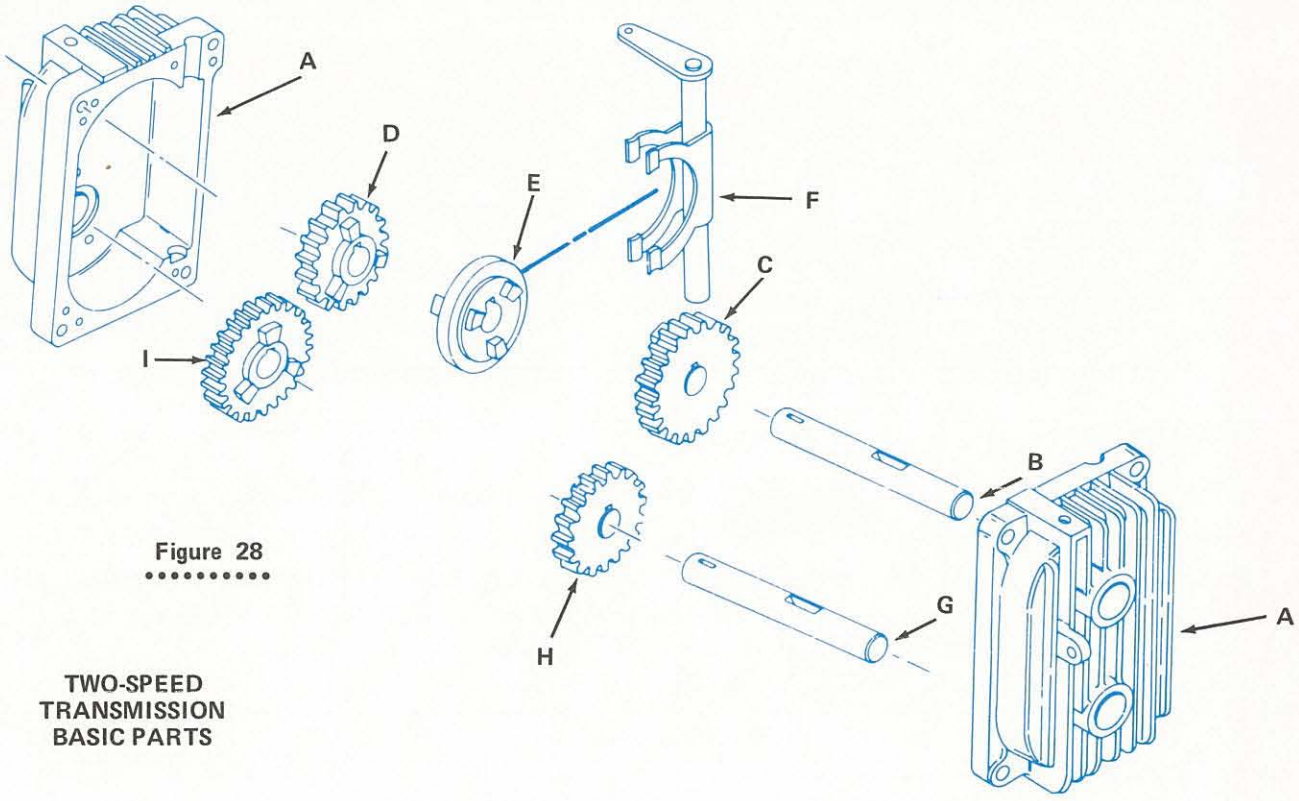


Figure 28

TWO-SPEED TRANSMISSION BASIC PARTS

The input shaft, shown at B, is driven by the engine. The two gears shown at C and D ride free on this shaft. These gears are not keyed to the shaft and are not driven by the input shaft itself. The shifter lug shown at E is keyed to the input shaft and turns at all times the input shaft is turning. This lug is keyed to the shaft so that it can slide back and forth along the shaft between gears C and D. It is moved along the shaft by the shifter fork shown at F. The handle of this fork extends through the housing so the gears can be moved from outside the housing.

The output shaft used to drive the equipment is shown at G. The two gears shown at H and I are driven by the gears on the input shaft. These gears are keyed to the output shaft and will drive the output shaft.

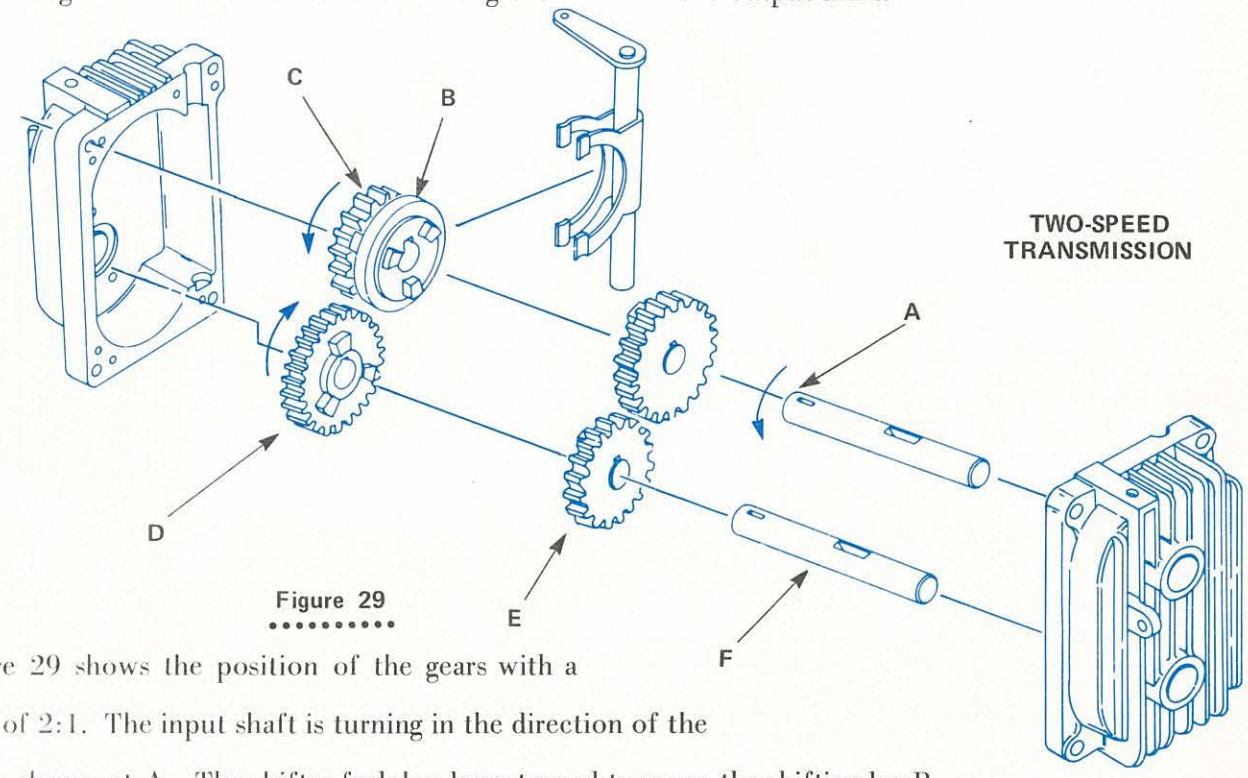


Figure 29

Figure 29 shows the position of the gears with a ratio of 2:1. The input shaft is turning in the direction of the arrow shown at A. The shifter fork has been turned to move the shifting lug B so it is in contact and begins driving gear C, which is a 20 tooth gear, in the direction shown by the arrow. The gear rides free and is not attached to the shaft but the shifter lug is keyed to the shaft and will turn gear C when it comes in contact with it because there are driving lugs on both the shifter lug and the gear. When gear C begins turning it starts to drive gear D, which is a 40 tooth gear, in the direction of the arrow. Now, this is the driven gear. Gear E is not turning because its matching gear on the input shaft is not keyed to the shaft. The output shaft F is now turning because it is being driven by gear D. The gear ratio of this drive is 2 to 1 (2:1). This means that the input shaft and gear C will have to make two complete revolutions in order to turn the output shaft and gear D one complete revolution. The output shaft will be turning half as fast as the input shaft. The 20 tooth gear C will have to make two revolutions in order to turn the 40 tooth gear D one revolution.

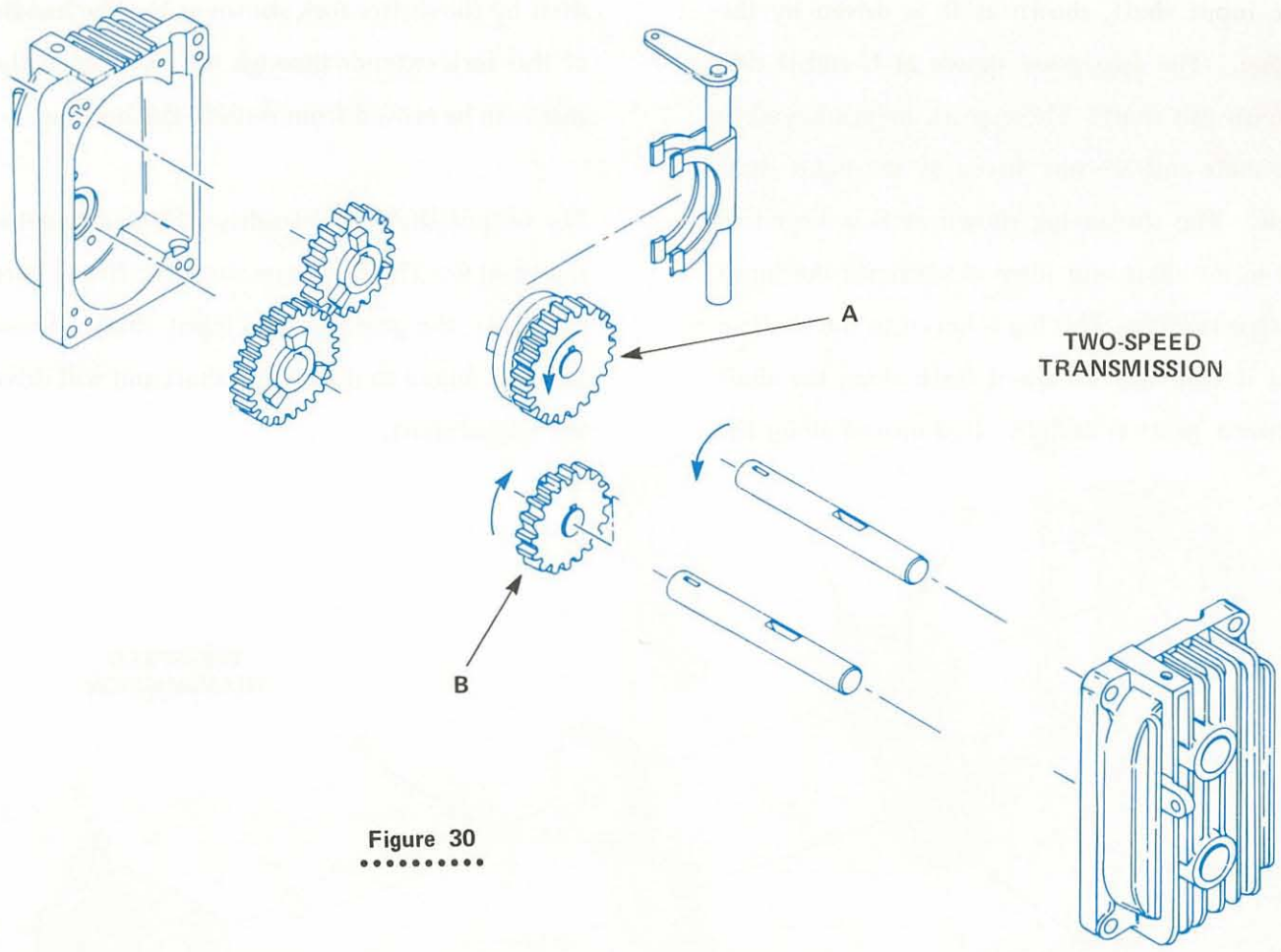


Figure 30

Figure 30 shows the shifter fork and driving shifter lug in contact with gear A. This is a 40 tooth gear. The input shaft is now driving this gear and it is turning gear B which is a 20 tooth gear. The gear ratio is now 1:2. The input shaft will have to make only one revolution in order to turn the output shaft two revolutions.

These are just the principles of gearing mechanisms. There are, of course, other parts involved. For the purpose of understanding the fundamentals of gear drives we are covering the basic methods of obtaining these mechanical actions. There are many different designs of power transmissions but most of them used with lawnmowers and other similar applications use one of these basic principles.

CLUTCHES

There are two basic types of clutches used with most small engine transmissions. The purpose of the clutch is to disengage the engine power from the transmission while the gears are being changed. Engines not using a transmission often use a simple clutching arrangement between the engine and the driven mechanism. This permits a direct in and out drive generally designed for one or two speeds.

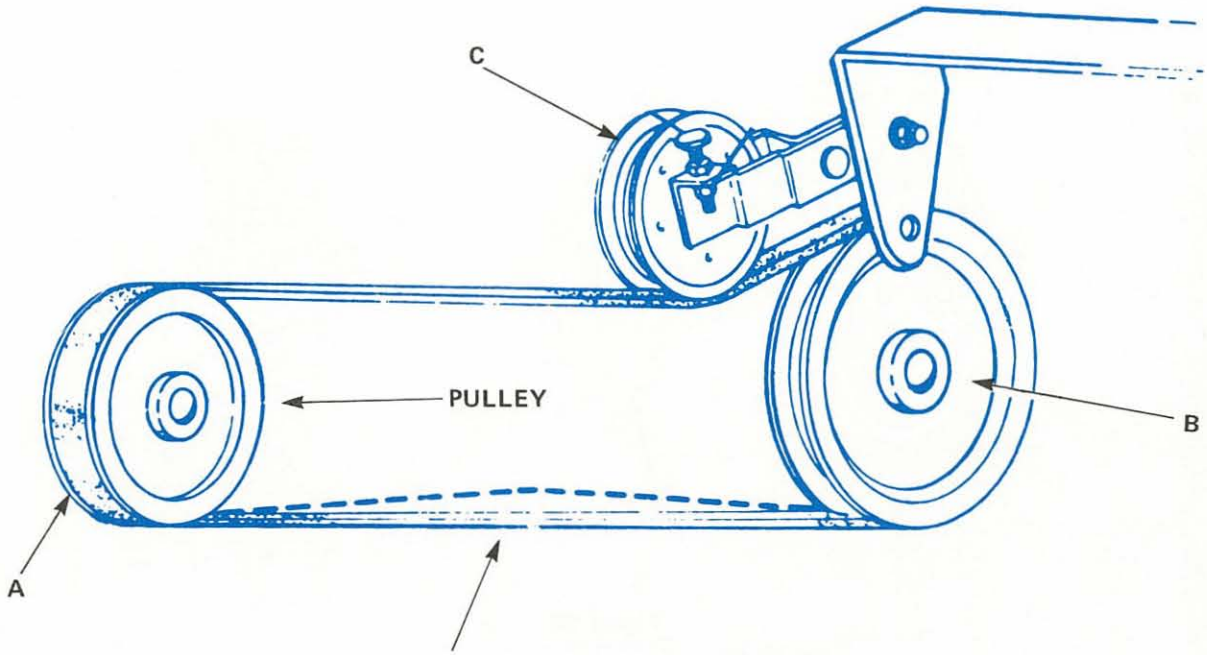


Figure 31

Figure 31 shows a typical clutch design used in a power transmission with many small engine applications. The pulley shown at A is driven by the engine. Pulley B can either be attached to the transmission or direct to the unit being driven. The other pulley shown at C is used to tighten the the belt D. In the position shown, the pulley C is riding tight against the belt, allowing the belt to transmit power from pulley A to pulley B. When pulley C is raised the belt becomes loose, allowing it to slip on both of the pulleys. With the belt loose, it will not transmit power to pulley B. This is one of the most simple forms of the belt clutch design.

Figure 32 shows another clutch design used with some small engines. This is the friction disc clutch. The part shown at A is the front clutch plate. The clutch facing is shown at B. The part shown at C is the moveable or rear part of the clutch plate. The clutch facing B transmits power from clutch plate C to platc A when all three units are compressed together. When plate C is turning and the three parts are not compressed together, no power is transmitted to plate A. With plate C turning and all three parts compressed together the facing B will transmit power to plate A.

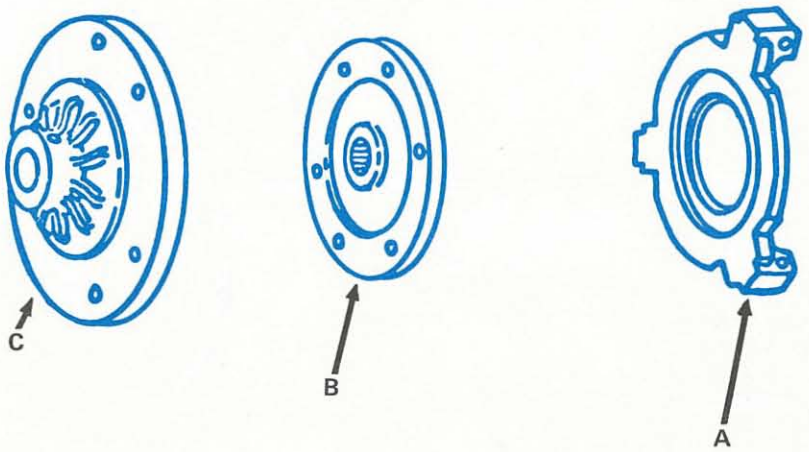
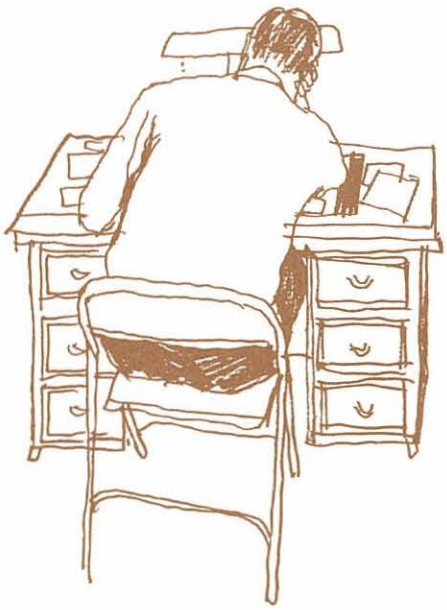


Figure 32

In this lesson we have covered the principles of the various drive and cutting functions of rotary power mowers. Different makes and models will have variations of these basic functions, however, these principles can be used for general servicing.

This completes the study material for this lesson. Complete the examination that follows, and then proceed on to the next lesson. **You will complete BOTH examinations and then mail them to us for grading.**



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

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(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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FINAL EXAMINATION
ON POWER MOWER REPAIR

LESSON NO 43

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(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

Examination questions for the Power Mower Section of the Small Engines Repair. True & False, filling in the missing word and multiple choice type questions.

1. Name the parts of the blade assembly shown in Figure 1.

   A _____

   B _____

   C _____

   D _____

   E _____

   F _____

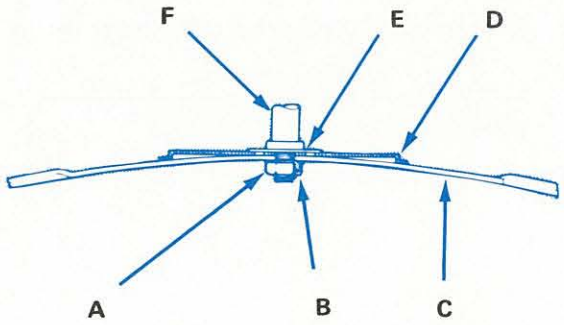


Figure 1

2. Name possible troubles that will cause improper blade tracing.

   A _____

   B _____

   C _____

   D _____

3. Name the three basic styles of cutting blades used on most rotary mowers.

   A _____

   B _____

   C _____

4. The raised area on the back side of the cutting edge is known as _____ .

5. Define the condition of the blade stiffeners shown in Figure 2.

   A _____

   B _____

   C _____

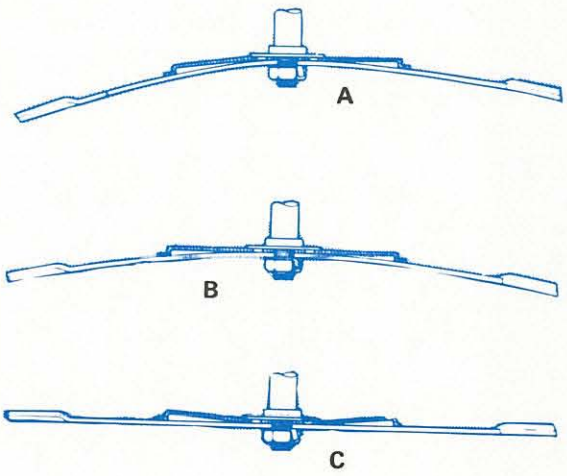


Figure 2

(Continued on page 2)

6. Any build up of foreign matter will cause the blade to be _____.

7. Cutting angles will sometimes vary from _____ to _____.

8. Golf greens require a blade sharpened at about 20 degrees.
   ☐ True
   ☐ False

9. _____ angle is recommended for average lawn cutting.

10. _____ angle is recommended for rough cutting, such as weeds and other rough usage.

11. Single blade, direct drive rotary mowers turn _____.

12. Looking down through the top of the engine and mower housing, the engine shaft of both two and four-cycle engines turn _____.

13. In addition to being sharp, the rotary blade must be _____.

14. Grinding on the back side of the blade cutting edge will destroy the _____.

15. Lawn mower vibration is almost always caused from the blade being _____ or a _____.

16. A mower blade will sometimes run smoother if the blade is aligned at right angles to the _____ and _____.

17. If the wheels are raised up, the cutting blade will be lowered.
   ☐ True
   ☐ False

18. Loss of engine power can also be caused by restricted _____ on two-cycle engines.

19. The basic principle of the bevel gear drive unit is to transmit the power from one _____ to another.

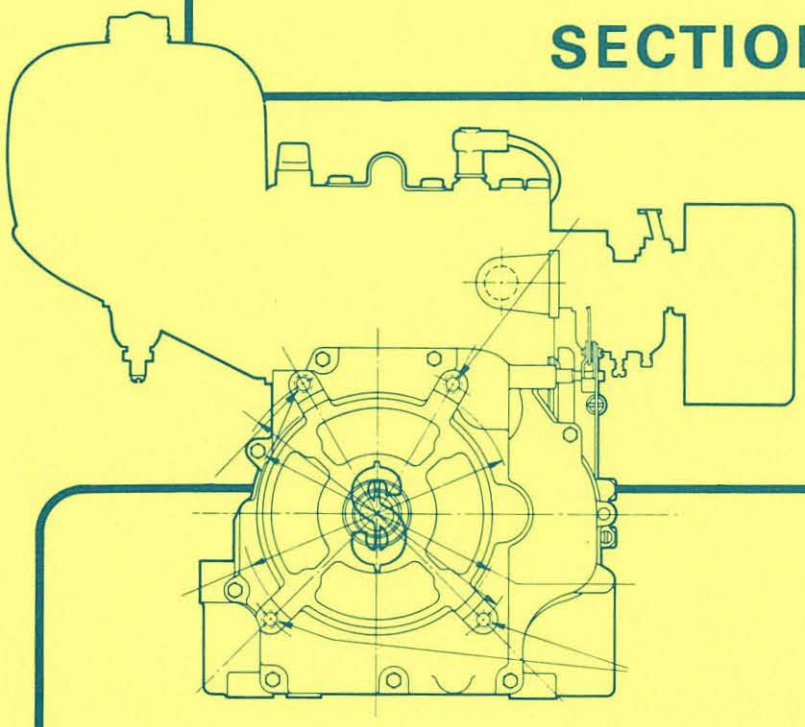
20. The purpose of the clutch is to disengage the _____ from the _____ while the gears are being changed.

Small Engine

Repair & Service

ADVANCED TRAINING

SECTION II



TURN THIS PAGE

...and let's find out all about --

CHAIN SAW REPAIR

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CHAIN SAW REPAIR

Table Of Contents

1 Chain Saw Operation
3 Fuel Mixture
3 Starting Chain Saws
4 Saw Kickback
4 Limbing
4 Felling
7 Bucking
8 Chain Saw Action
9 Clutch
12 Chain Drive Sprockets
13 Drive Sprocket Pitch
14 Guide Bar
15 Guide Bar Troubles
17 Guide Bar Maintenance
19 Chain Construction
20 Types of Cutters
20 Parts of the Cutter
21 Chain Pitch
22 Depth Gauge Settings
22 Chain Pitch and Depth Gauge
23 Cutter Action
24 Drive Links
25 Cutting Angles
28 Chain Tension
29 Chain Adjustment
30 Loose Chain
30 Chain Breakage
31 Chain Drive Link Damage and Causes
34 Cracked Cutters and Side Links
34 Repairing Chains
36 New Chains
36 Filing Chain Cutters
39 Filing Depth Gauges
40 Correct and Incorrect Filing
43 Model 550 Chain Saw Grinder
43 Dressing Grinding Wheels
44 Operating the Machine
44 Grinding Cutters
45 Top Plate Angle
45 Side Plate Angle
45 Removing Abrasive Damage
46 Adjustment
46 Points to Follow Prior to Grinding
47 Depth Gauge Control
48 Chain Lubrication
49 Chain Oiler System
54 Protective Devices
55 Muffler and Flame Arrestor
57 Air Cleaners

CHAIN SAW OPERATION

Chain saws are sometimes considered part of a special industry. However, in recent years engineering design and production have brought them down in price. They are now rapidly becoming part of the machinery and tool inventory of most farmers and many people living in suburban areas. The chain saw is relatively new in the wood sawing field. It has been used for a number of years for logging operations, but it has just been in the last few years that the light-weight saw was developed and mass produced so the price could be brought into the range of the individual owner.

The chain saw is really a very simple machine. It consists basically of a two-cycle engine, clutch and sprockets to drive a chain around a bar. The engine has the same basic design as the two-cycle engines used on lawnmowers and other similar applications. Ignition, carburetion and starting are similar to other two-cycle engines. Engine tolerances and construction are generally more critical because these engines must be made of very light-weight material and operate at very high speeds to develop the required horsepower and torque.

Many of the following chain saw illustrations were supplied by, and used through the courtesy of *Ken Cook Transnational, Milwaukee, Wisconsin.*

The basic working assemblies that make up the construction of the chain saw are shown in Figure 1. The engine, or power head, as it is sometimes called, is shown at A. This is a two-cycle engine. Some very old chain saws used four-cycle engines that had special transmissions that would allow the sawing mechanism to rotate at different angles so the engine would remain in an upright position. These were made many years ago and few of them are still around.

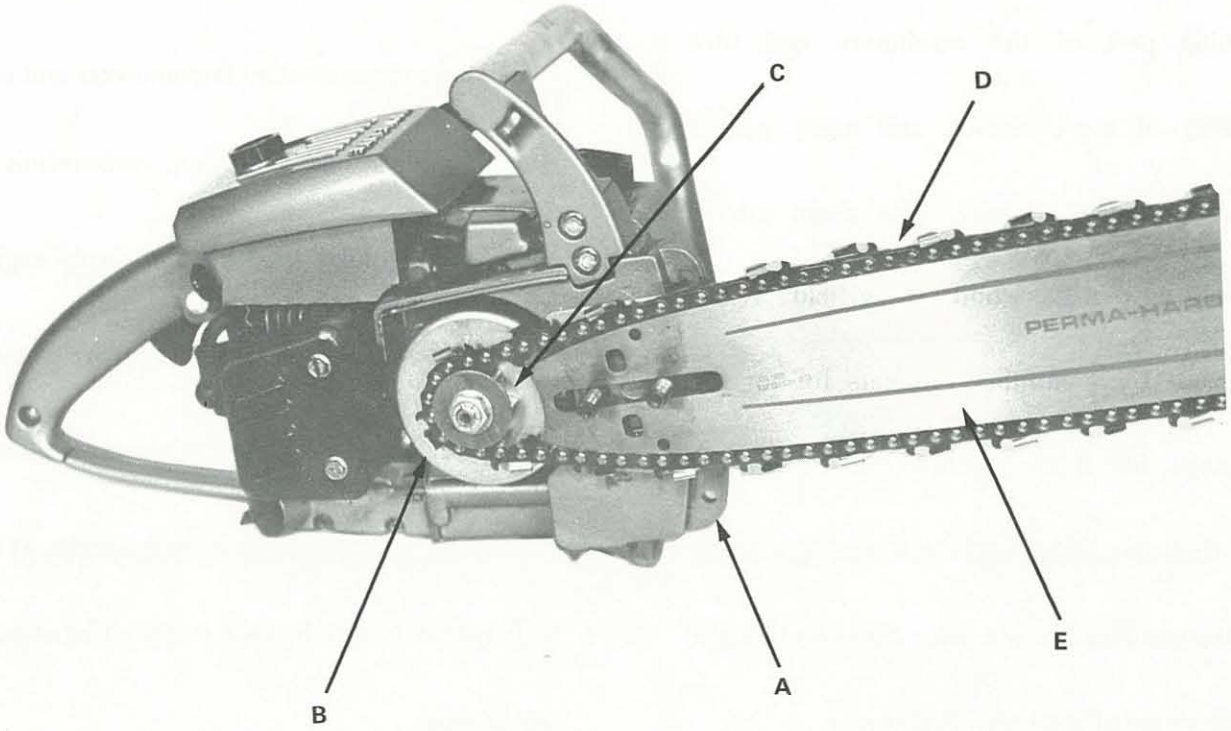


Figure 1

The clutch shown at B is attached directly to the engine crankshaft. As the engine speed is increased to its operating speed the clutch engages the drive sprocket shown at C which turns the chain shown at D. When the engine is idling the clutch does not drive the sprocket and the chain does not turn. The bar shown at E had a groove around the outside edge for the chain to ride in.

FUEL MIXTURE

We'll cover the principles and operation of these working assemblies later. Before going into the actual chain saw construction we'll cover the basic functions the chain saw is designed to accomplish. First, since this is a two-cycle engine, it will require a mixture of fuel and oil in the fuel tank. Different makes and models recommend from 1/4 to 1/2 pint of SAE-30 oil with each gallon of regular gasoline. Fuel mixture will often be given on the engine. Always follow the specifications given by the manufacturer when available.

Using 1/2 pint SAE-30 oil with each gallon of regular fuel is generally adequate for most engines. If the engine smokes excessively you can reduce the oil mixture, but never lower than 1/4 pint per gallon.

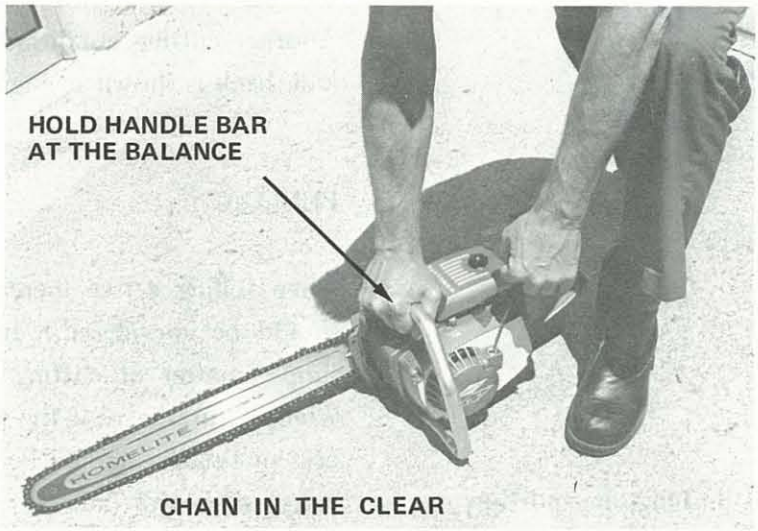


Figure 2

STARTING CHAIN SAWS

Chain saws can be very dangerous and must be handled with extreme care. Figure 2 shows the proper way to start a chain saw. If the saw frame is not held firmly, an engine kickback could cause the saw to kick up toward the operator or dig into the ground. Always have two points holding the saw as shown. Be sure the chain and bar are free of any obstruction.

Normally the chain will not begin turning until the engine is speeded up and the clutch begins driving the sprocket. In case the clutch or the throttle linkage is out of adjustment, the chain could begin turning as soon as the engine starts.

SAW KICKBACK

The cutting action of a saw chain makes it either want to dig into the log or kick back away from the log. Figure 3 shows a typical cutting position. The chain is digging into the log at the position shown at A. The cutting action of the chain is pulling the saw down into the log. If the saw becomes pinched or hits another branch as shown at B the saw would have a tendency to kick back in the direction of the arrow.

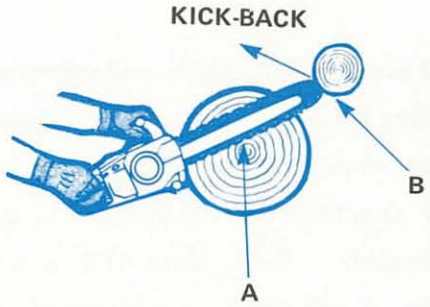


Figure 3

Even small chain saws can kick back with a great deal of force. To prevent accidents, stand with your weight evenly distributed on both feet. Hold the saw firmly with both hands at all times. Another cutting condition that will make the saw kick back is shown in Figure 4.

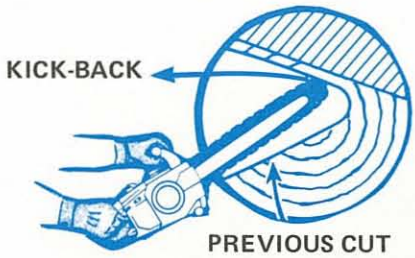


Figure 4

LIMBING

For small work such as limbing, any portion of the top or bottom of the bar and chain can be used if the saw is held firmly. To remove small limbs as shown in Figure 5, make the first cut shown at A with the top of the bar from the bottom. Make the second cut on the top at B.

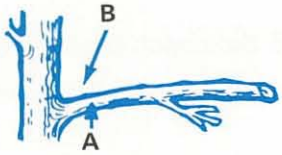


Figure 5

FELLING

When felling a tree there are several factors that should be considered. In most cases it is not a simple matter of cutting the trunk until it falls. Wind, natural lean of the tree, balance and soundness of the tree should be considered when felling a tree so it will fall with the greatest amount of safety. Keep an area of about one-fourth the way around the tree clear as shown in Figure 6. This is for operator safety since trees are often unpredictable in their line of fall. They will often hit something and kick back so it is important for the operator to have a clear path of retreat.

Figure 6

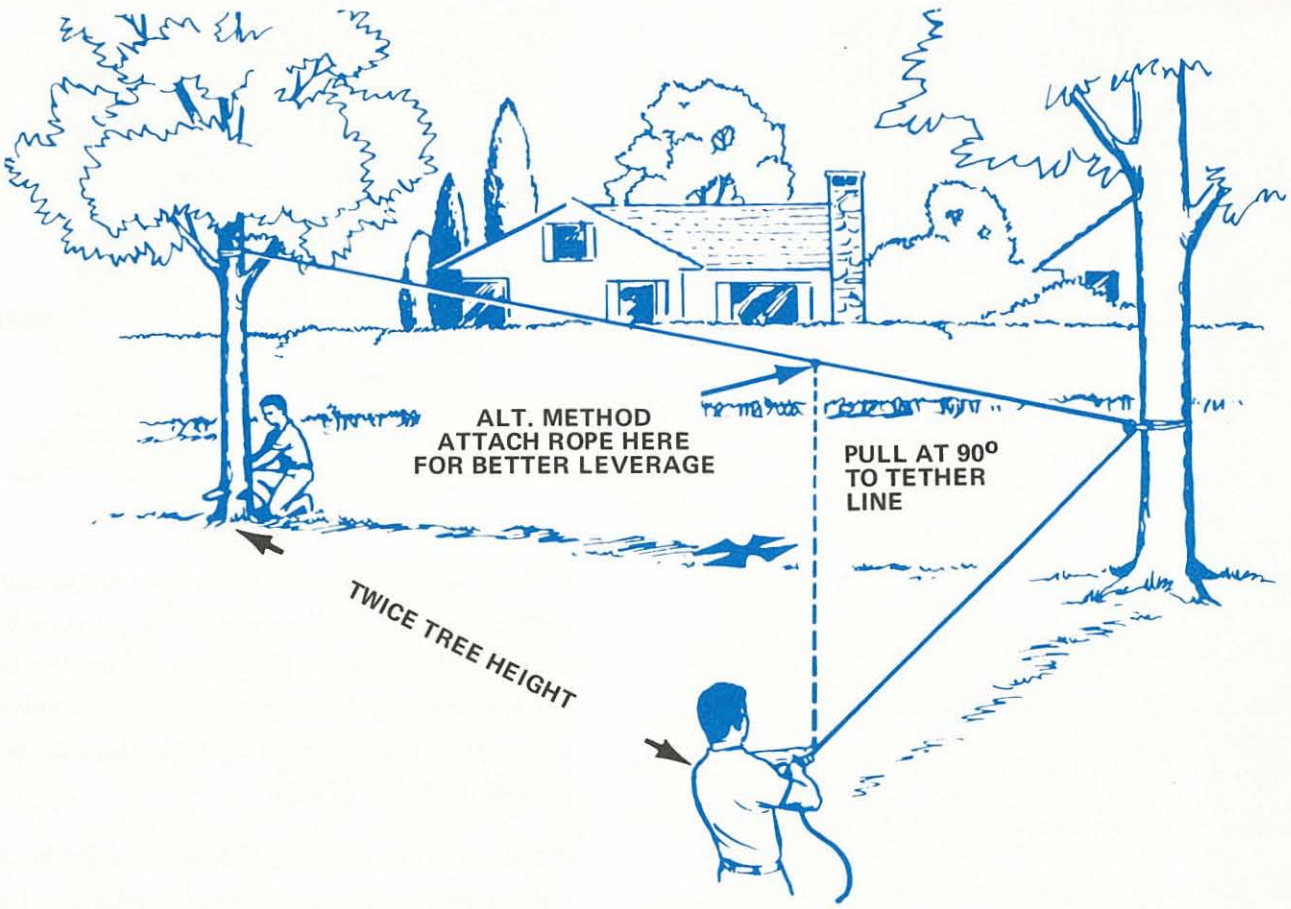


Figure 7

Another method of felling is to force the tree to fall with the help of ropes and pulleys as shown in Figure 7. Often the natural conditions will make it impractical to fell the tree without damage to other trees or structures. You can force the tree to fall in the desired direction by using ropes and pulleys as shown in Figure 7.

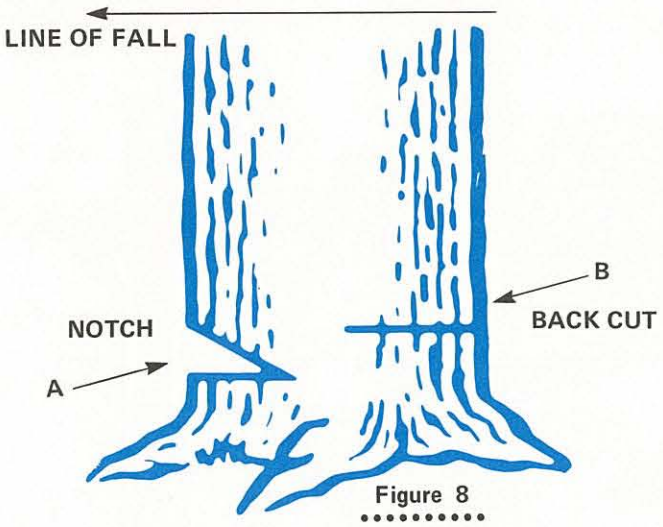


Figure 8

After deciding which way the tree is to fall notch the trunk as shown in Figure 8. The notch should be about one-third the diameter of the trunk as shown at A and perpendicular to the line of fall as shown by the arrow. The back cut can then be made at B. The back cut should be at least 2 inches higher than the notch. This will leave a hinge of uncut wood to help guide the tree over.

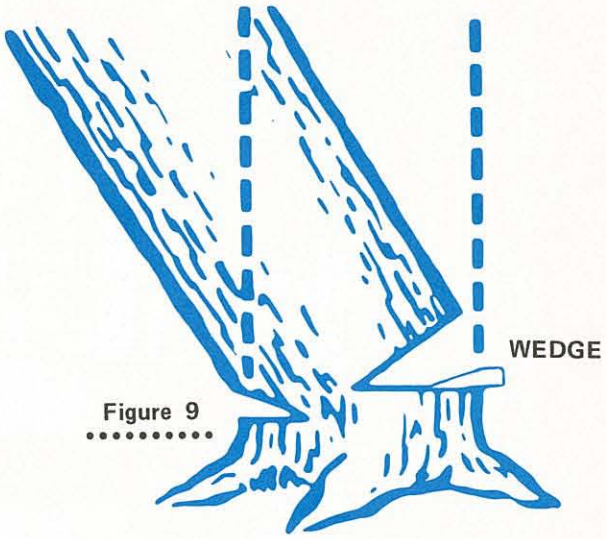


Figure 9

If there is any chance that the tree might not go over in the desired direction, or might rock back and bind the saw, stop cutting before the back cut is complete. Use a plastic wedge as shown in Figure 9 to open the cut and tilt the tree in the desired direction of fall.

Plastic or wooden wedges should always be used with chain saws, never steel wedges. Large diameter trees should always be wedged over in this manner. Always leave the hinge part, between the notch cut and the back cut, to help guide the tree.

Figure 10 shows a cross section view of a typical felling operation. First, the notch cut is made at A, then the back cut at B. Wedges are then driven in the back cut to widen it and tilt the tree. The hinge part at C should be left to help guide the tree in the proper felling direction.

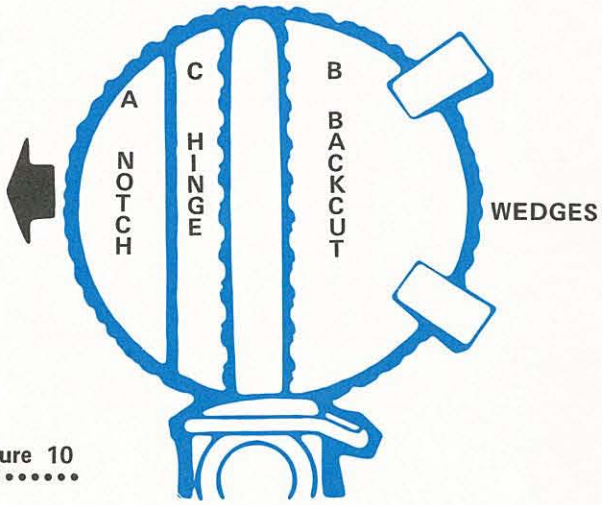


Figure 10

FLAT ON GROUND BUCK FROM TOP

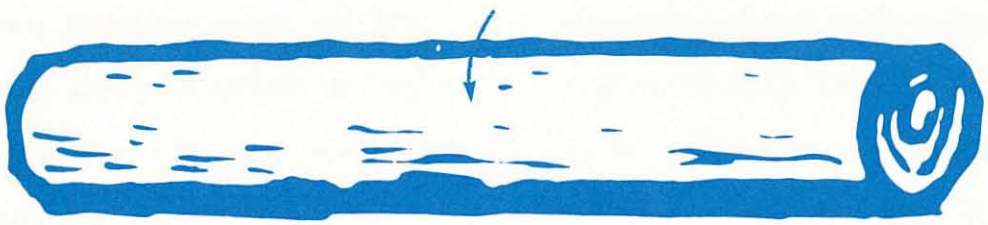


Figure 11

BUCKING

Most logs supported along their entire length, as shown in Figure 11, can be cut through from the top but will sometimes require the use of wedges. Often this cutting condition will permit rolling the log and avoid the use of wedges.

SUPPORTED ON ENDS
FIRST THIRD FROM TOP
REST FROM BOTTOM

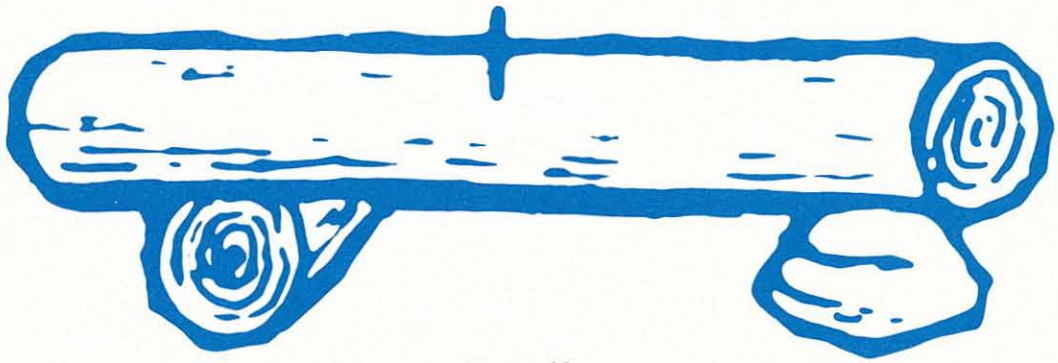


Figure 12

If a log is supported on both ends, as shown in Figure 12, the first third of the log should be cut through from the top and the rest from the bottom.

Proper use of a chain saw can have a great deal to do with the life of the saw. It is important that the mechanic servicing these units have some knowledge of their correct operating principles. Excessive binding of the blade will shorten the life of both the guide bar and the chain. It can also cause damage to the engine and related parts by throwing excess strain on them.

CHAIN SAW ACTION

If the chain drive sprocket was attached directly to the crankshaft the chain would be driven at any time the engine was running. To avoid this a clutch is used between the engine crankshaft and the chain drive sprocket. The clutch is designed so it will not turn the drive sprocket until the engine crankshaft reaches adequate speed to develop the power necessary to drive the chain. When the engine is idling the clutch will not drive the chain. When the engine reaches about 2600 RPM the clutch will engage and begin driving the chain drive sprocket.

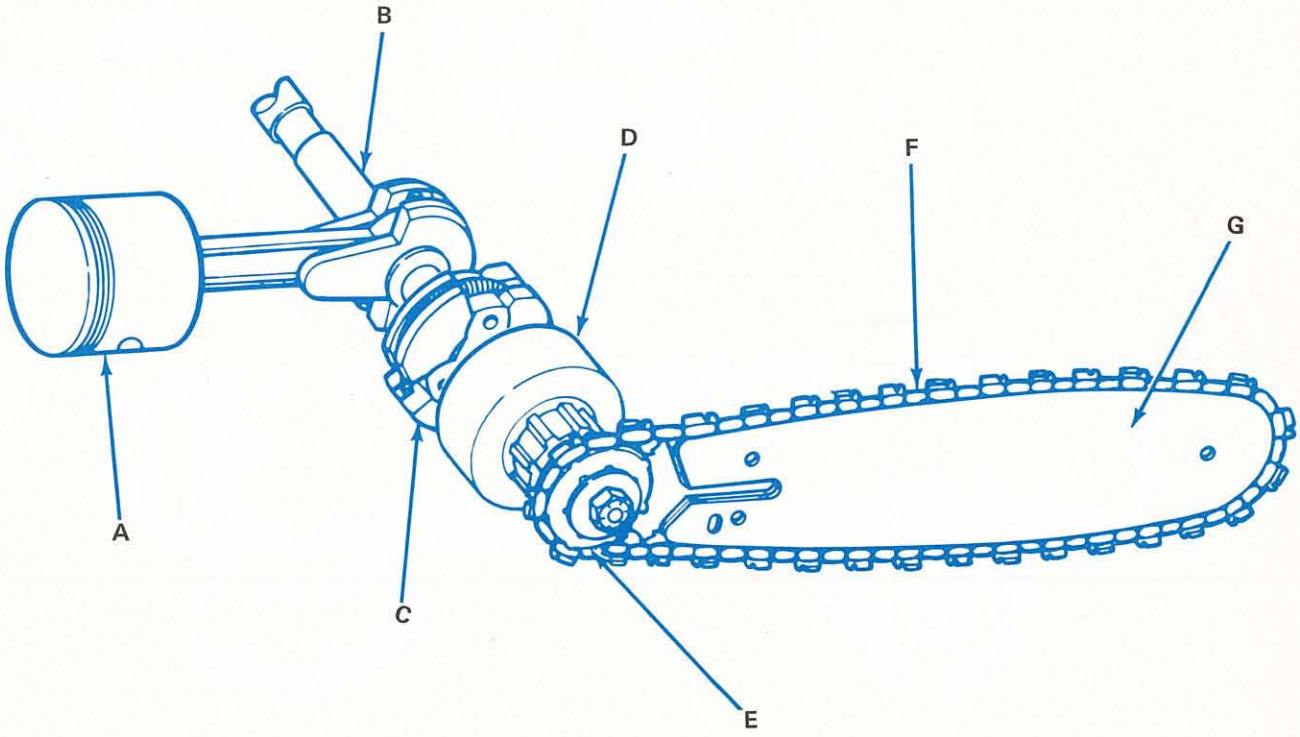


Figure 13

Figure 13 shows the driving mechanism of a typical chain saw. The piston, shown at A, turns the crankshaft B. The clutch shoes, shown at C, are attached directly to the crankshaft and turn at all times the crankshaft is turning. The clutch shoes are designed so they will expand when the crankshaft reaches a speed of about 2600 RPM. When the shoes expand they will contact the clutch drum shown at D and begin turning it. The drum is attached directly to the sprocket shown at E, which drives the chain F around the bar G. This is the basic principle of a chain saw action.

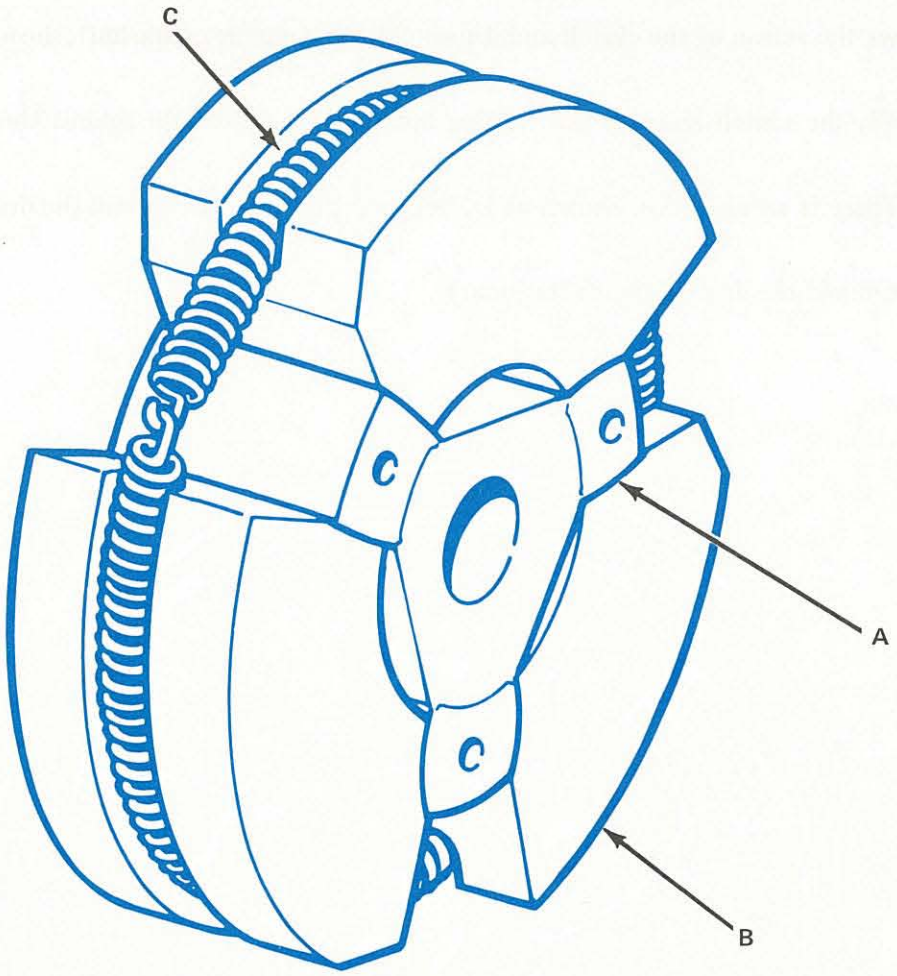


Figure 14

CLUTCH

Most chain saw clutches operate on the principle of centrifugal force, similar to the centrifugal governors we studied earlier. A typical clutch design is shown in Figure 14. There are only three basic parts of the clutch driving mechanism. The driver shown at A is attached directly to the engine crankshaft. The clutch shoes shown at B are made of a friction material and are held in place on the driver by the spring shown at C. The spring tension and weight of the clutch shoes are designed so centrifugal force of the shoes overcomes the tension of the spring, when the engine crankshaft reaches about 2600 RPM. The shoes then begin to move away from the driver. If this clutch is operated without being contained in a drum, it would fly apart when centrifugal force reached the point of overcoming the tension of the spring. When repairing a saw, never run the engine with the clutch shoes on the shaft without the drum in place.

Figure 15 shows the action of the clutch and drum. With the engine crankshaft, shown at A, turning at less than 2600 RPM, the clutch shoes B are turning but they are held tight against the driver, by the spring shown at C. There is an air space, shown at D, between the clutch shoes and the drum. The shoes do not contact the drum and the drum remains stationary.

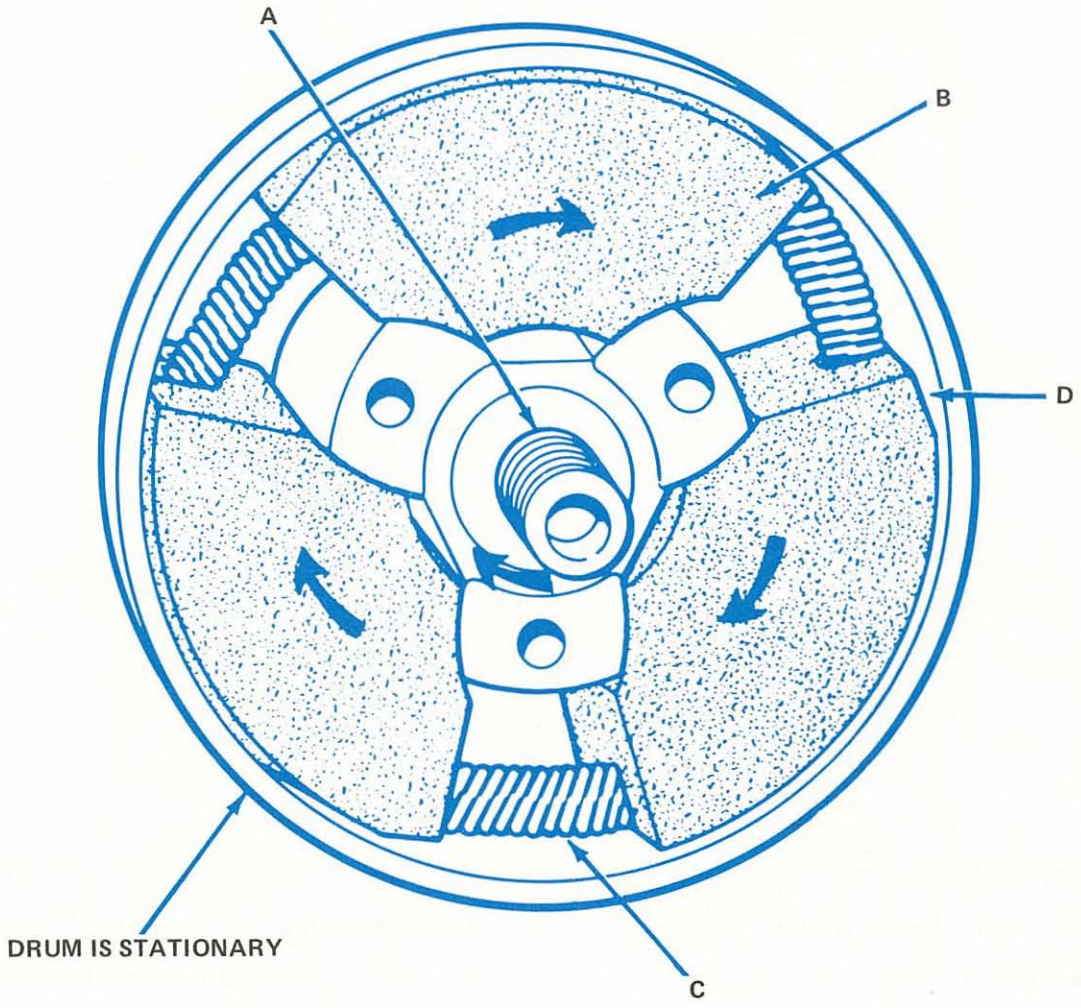


Figure 15

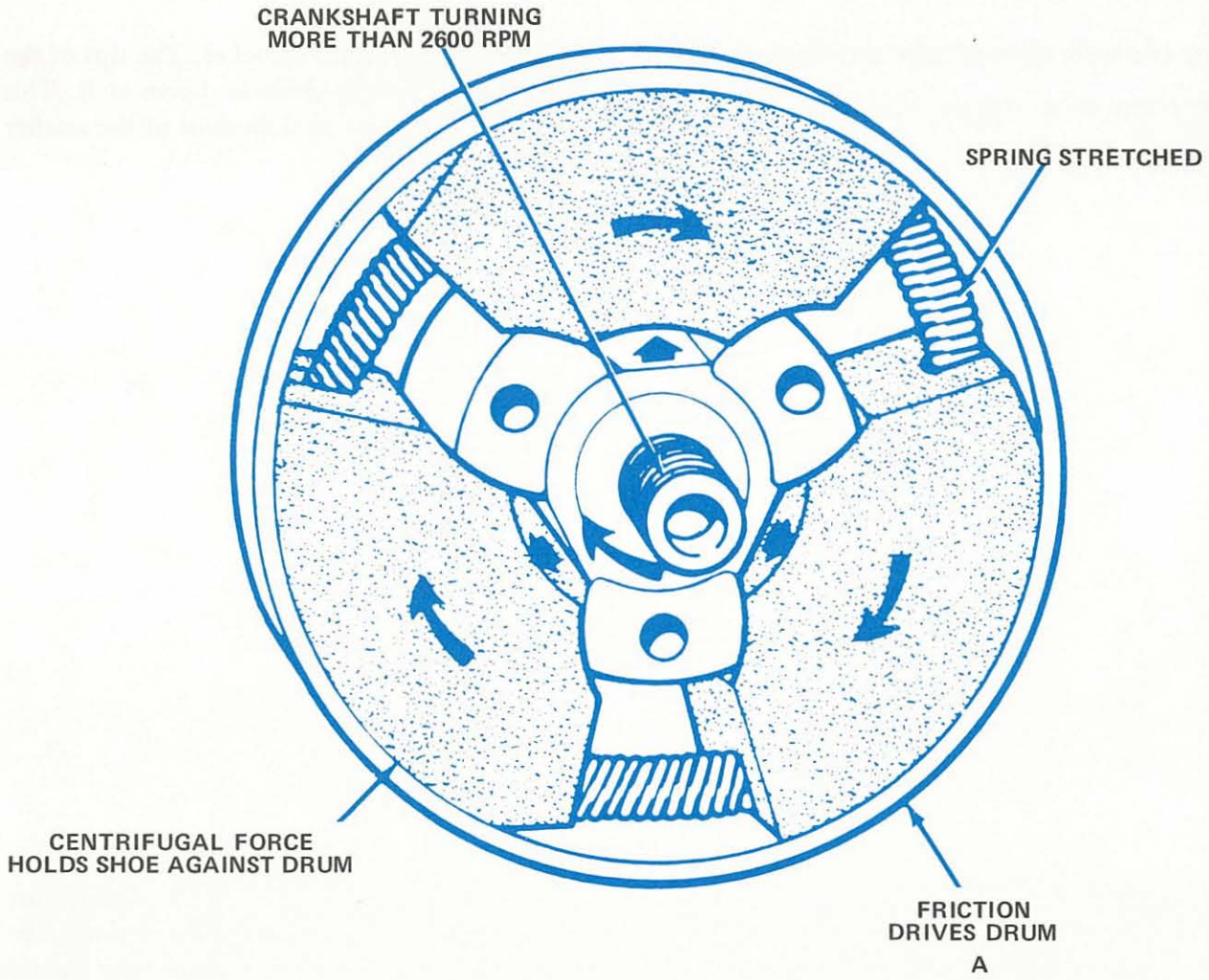
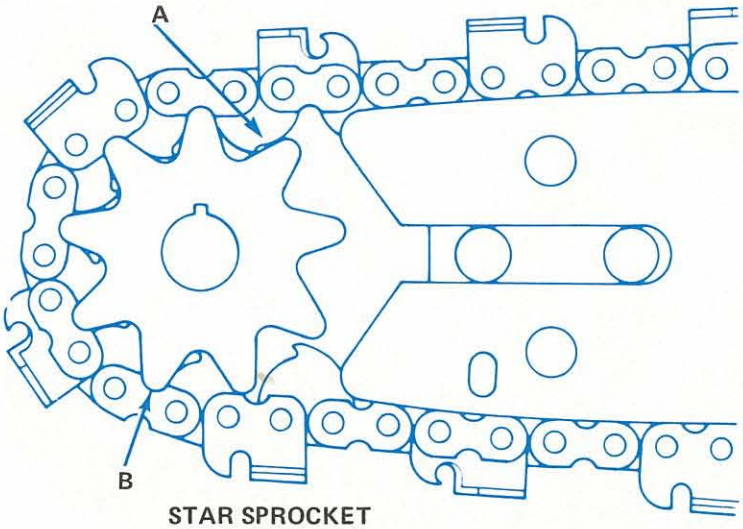


Figure 16

Figure 16 shows the crankshaft turning in excess of 2600 RPM. Centrifugal force overcomes the tension on the spring and allows the shoes to come in contact with the drum surface shown at A. When this happens, the outside drum begins turning at the same speed as the engine shaft. Friction between the shoes and the drum holds them together.

CHAIN DRIVE SPROCKETS

There are two basic types of drive sprockets used on most chain saws. Figure 17 shows the star sprocket. The chain driver links, shown at A, are designed so they fit the sprocket. The tips of the sprocket support the chain as shown at B. This is the type sprocket used on most of the smaller chain saws.

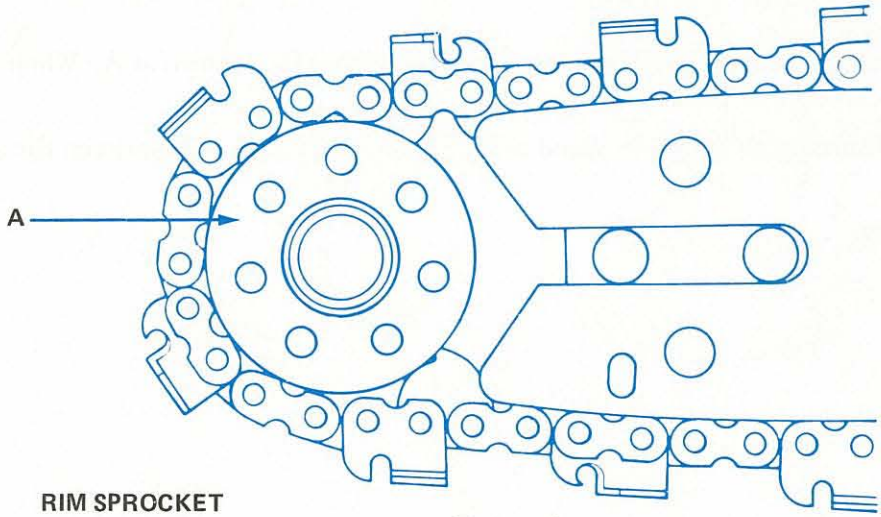


STAR SPROCKET

Figure 17

Another sprocket used on many of the larger chain saws is shown in Figure 18. This is the rim sprocket. This sprocket gives a little more support to the chain. The chain side links and cutters ride between flanges shown at A. This type sprocket is generally designed to float on the drum spline to keep it in alignment with the chain.

Worn sprockets cannot be repaired. They must be replaced or they will damage the chain. Since sprockets are relatively inexpensive they should be replaced at the first sign of wear. Never install a new chain on old sprockets. New chains and sprockets should always be replaced at the same time. After a chain has run on bad sprockets for only a short time it will begin to wear the drive links.



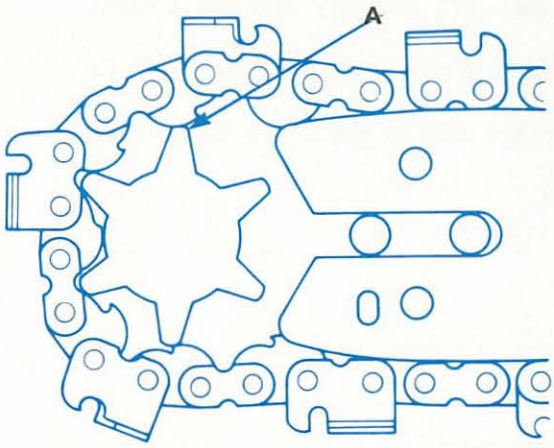
RIM SPROCKET

Figure 18

DRIVE SPROCKET PITCH

Chain pitch must be matched to the sprocket pitch. Sprocket pitch is the distance between the point of the driving tip of the sprocket tooth and the base of the tooth.

Figure 19 shows a sprocket with too much pitch. This condition allows the driving links of the chain to ride too high on the teeth of the sprocket as shown at A. The chain drive links will begin wearing grooves in the sprocket at the tip.

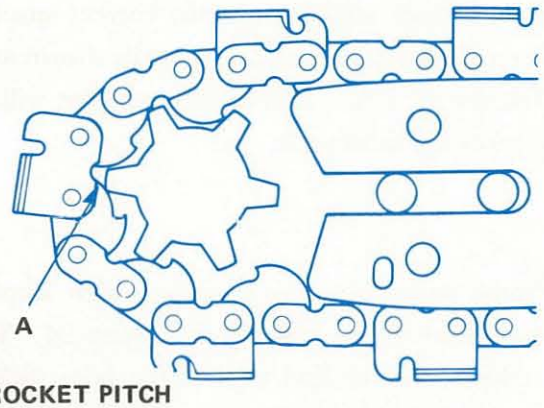


SPROCKET PITCH
TOO GREAT

Figure 19

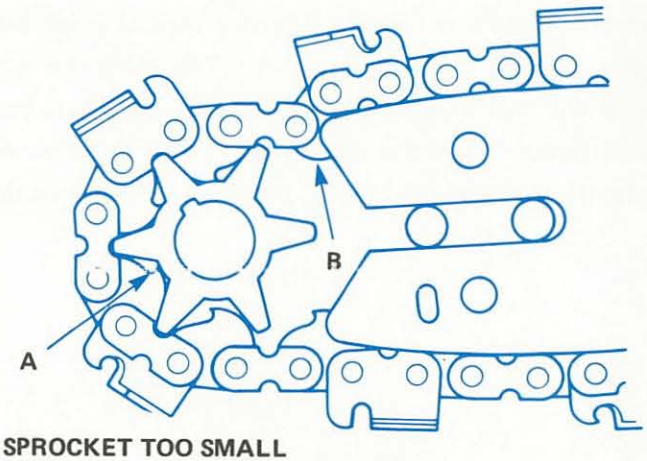
If the sprocket is too small, as shown in Figure 20, it will allow the drive links of the chain to ride up on the tips of the sprocket as shown at A. This will cut a groove in the sprocket.

The drive sprocket must also be the proper size to match the bar as shown in Figure 21. If the sprocket is too small the drive links will ride too low in the sprocket as shown at A. The chain will drop down at the point it begins to enter the groove of the bar as shown at B. This condition will cause the chain to pound the bar at this point and begin to damage both the bar and the chain.



SPROCKET PITCH
TOO SMALL

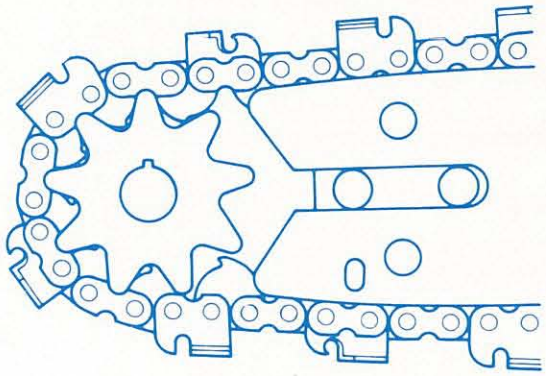
Figure 20



SPROCKET TOO SMALL

Figure 21

Figure 22 shows the correct sprocket pitch and size. The drive links contact the sprocket properly and the correct diameter sprocket permits the chain to enter the slot in the bar at the proper angle.



CORRECT MATCH

Figure 22

GUIDE BAR

The guide bar supports the chain as it is driven by the drive sprocket. The guide bar construction looks like a steel plate, with a milled groove around the outside edge. Actually it is three individual pieces of metal laminated together by a welding process.

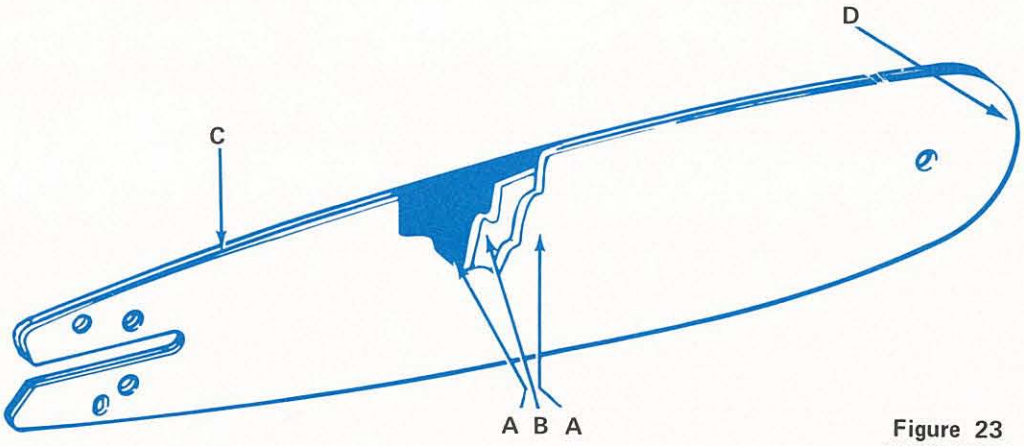


Figure 23

Figure 23 shows a cut-away view of a typical guide bar. The two outside pieces shown at A, are welded together so they are perfectly flat. The thickness of the piece shown at B permits the correct spacing between the two outside plates for the drive links to run between. The outside edge of the rails shown at C are heat treated for extra hardness and also the nose of the bar shown at D. Often this nose part will be plated with a special hard metal, such as stellite, since this area takes the most wear.

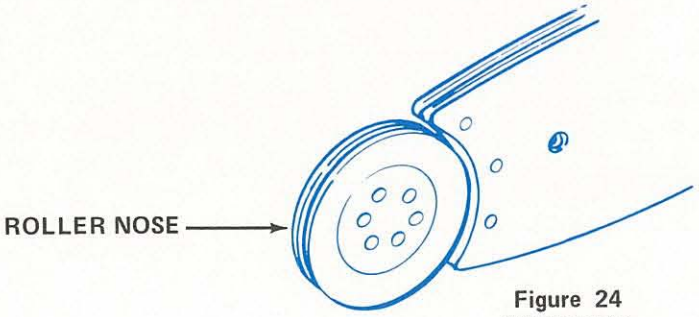


Figure 24

Some larger saws are equipped with a roller nose that turns, as shown in Figure 24. This reduces friction and wear at the nose section as the chain is actually rolling around the nose pulley instead of sliding around the groove.

GUIDE BAR TROUBLES

Pitch and sawdust accumulating in the groove of the guide bar are very common causes of damage to both the bar and chain. If an accumulation of foreign matter is allowed to build-up in the bar groove, as shown in Figure 25, the chain will ride too high and weave. The bar groove is shown at A. If build-up accumulates in the groove the driver will ride high as shown at B. This allows the chain to weave so it is hard to cut straight. It causes excess chain wear and will often cause chain breakage. This area should be checked frequently and cleaned out with a sharp cornered scraper approximately the same thickness as the chain drivers.

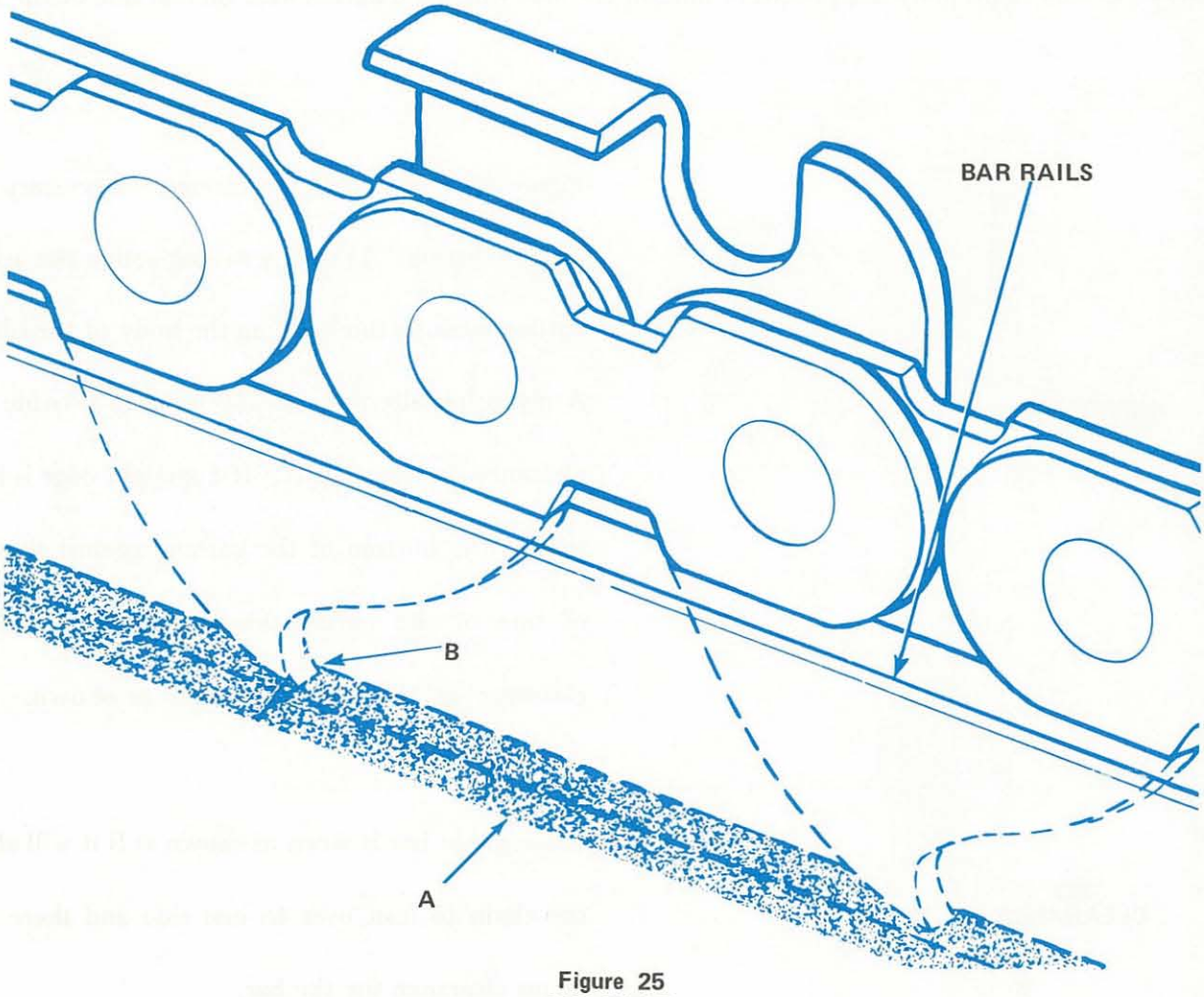


Figure 25

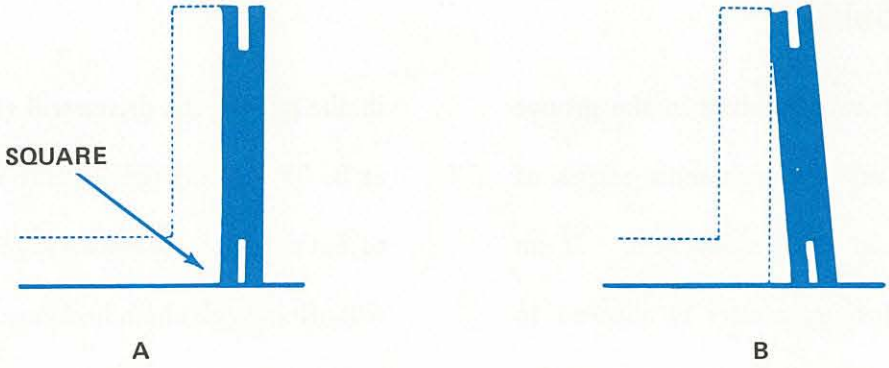
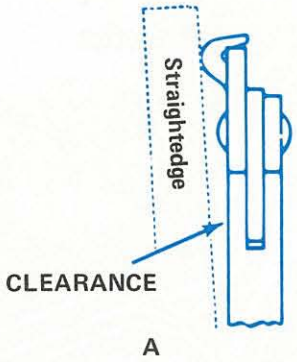


Figure 26

The guide bar rails must be square as shown in Figure 26. Using any square measuring device the bar should stand up straight as shown at A. If the bar leans to one side as shown at B, one of the rails is low from wear on one side. This condition is often caused from the chain being dull on one side or improperly sharpened. A chain improperly sharpened, or dull on one side will cause excess wear on one side of the bar.



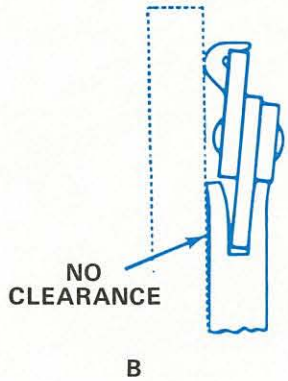


Figure 27

Figure 27 shows the side clearance necessary for proper cutting. As in any sawing action the actual cutting must be thicker than the body of the blade. A chain has alternate cutting teeth to provide the clearance necessary at A. If a straight edge is held against the bottom of the bar and against the top of one of the cutting lengths, there should be clearance at the top of the bar as shown.

If the guide bar is worn as shown at B it will allow the chain to lean over to one side and there will be no clearance for the bar.

Figure 28 shows how the depth of the bar groove should fit the chain. The chain tie straps should fit flush on top of the bar as shown at A-1. This leaves a clearance at the bottom between the chain and the bar.

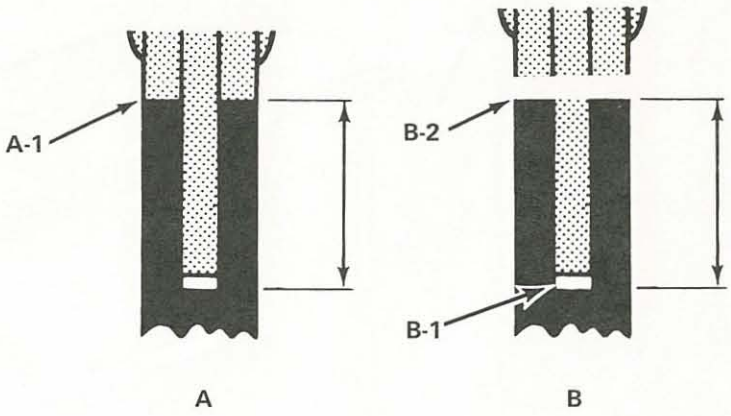


Figure 28

If either the chain tie straps wear or the guide bar groove fills with foreign matter, as shown at B-1, it will cause the chain to ride high at B-2. This will allow the chain to move back and forth sideways and begin wearing the groove wider at the top as shown at B in Figure 27.

GUIDE BAR MAINTENANCE

The guide bar must be clean at all times. The groove should be checked and cleaned if necessary. Lubricating oil enters the guide bar groove through the oil holes shown in Figure 29. There are two holes shown at A and B. Oil enters these holes and goes directly to the guide bar groove that the chain rides in. The chain oil is then picked up by the moving chain and oil is carried along the entire bar groove.

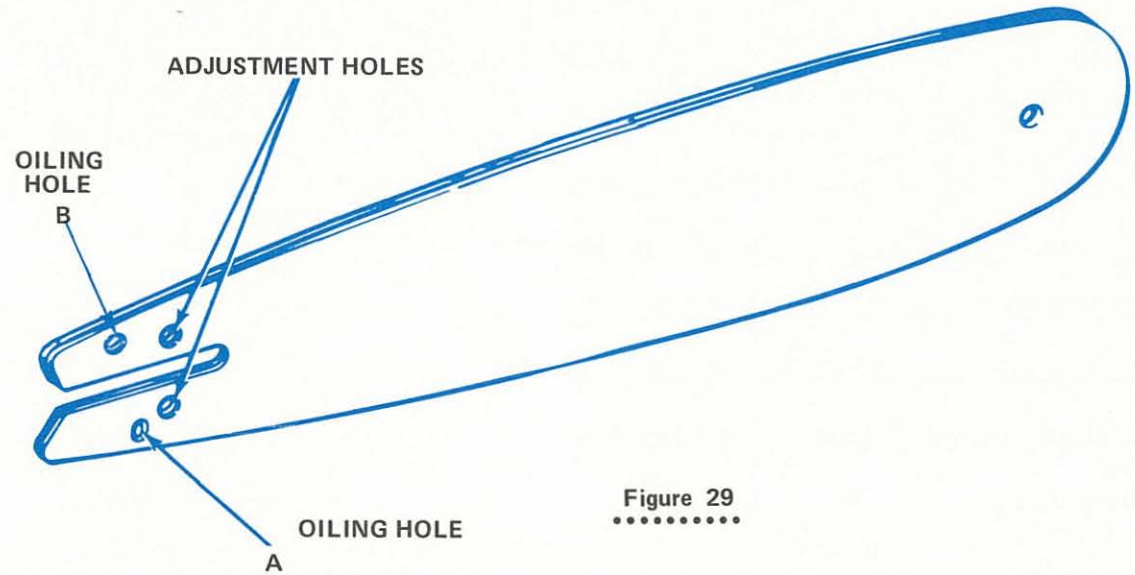


Figure 29

Due to the direction of chain travel some parts of the guide bar are subject to more wear than others. Because of this the bar is made so it can be turned over. This will distribute the wear more evenly and make the bar last much longer.

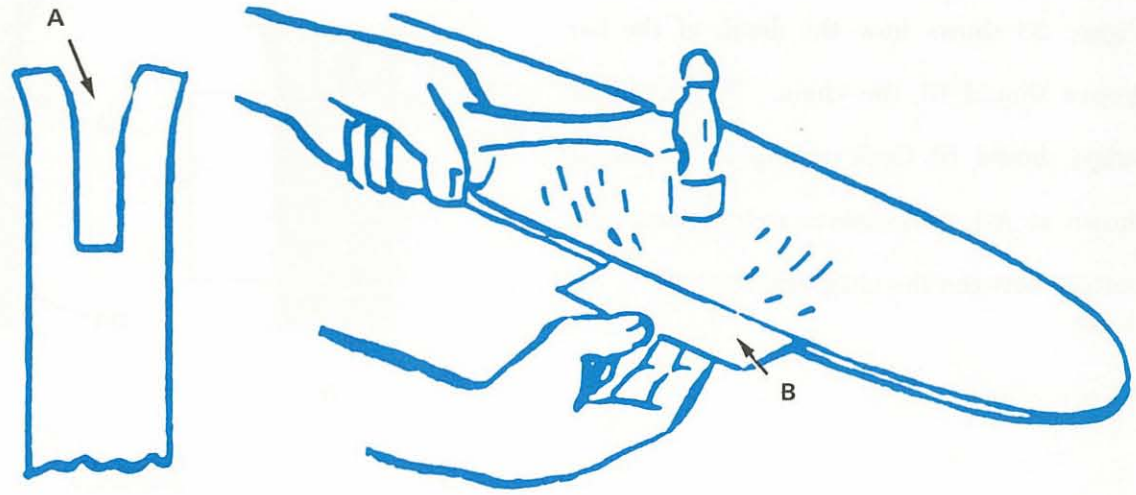


Figure 30

If the guide bar groove is spread as shown at A in Figure 30 it can be closed. Lay the bar on a flat piece of heavy steel. Use a shim as shown at B that is about .004 inch thicker than the drive tangs of the chain. Slip the shim in the bar groove all the way and lightly hammer the bar edge to close it. Move the shim all the way around the bar and continue closing.

After a worn guide bar has been closed, it is necessary to open up the front end of the bar so the chain will enter easily. Figure 31 shows the condition of the bar at A after it has been closed. The end of the bar should be opened as shown at B. The chain is traveling in the direction of the arrow. By opening the guide groove at this point it will make it easier for the chain to enter the groove.

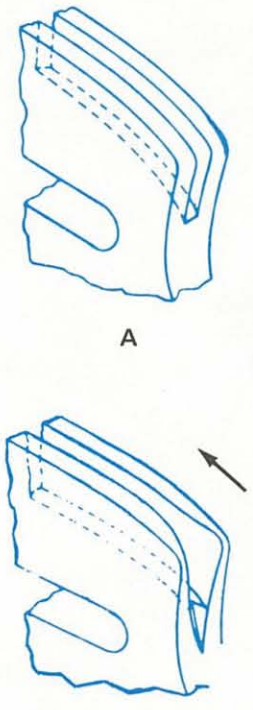


Figure 31

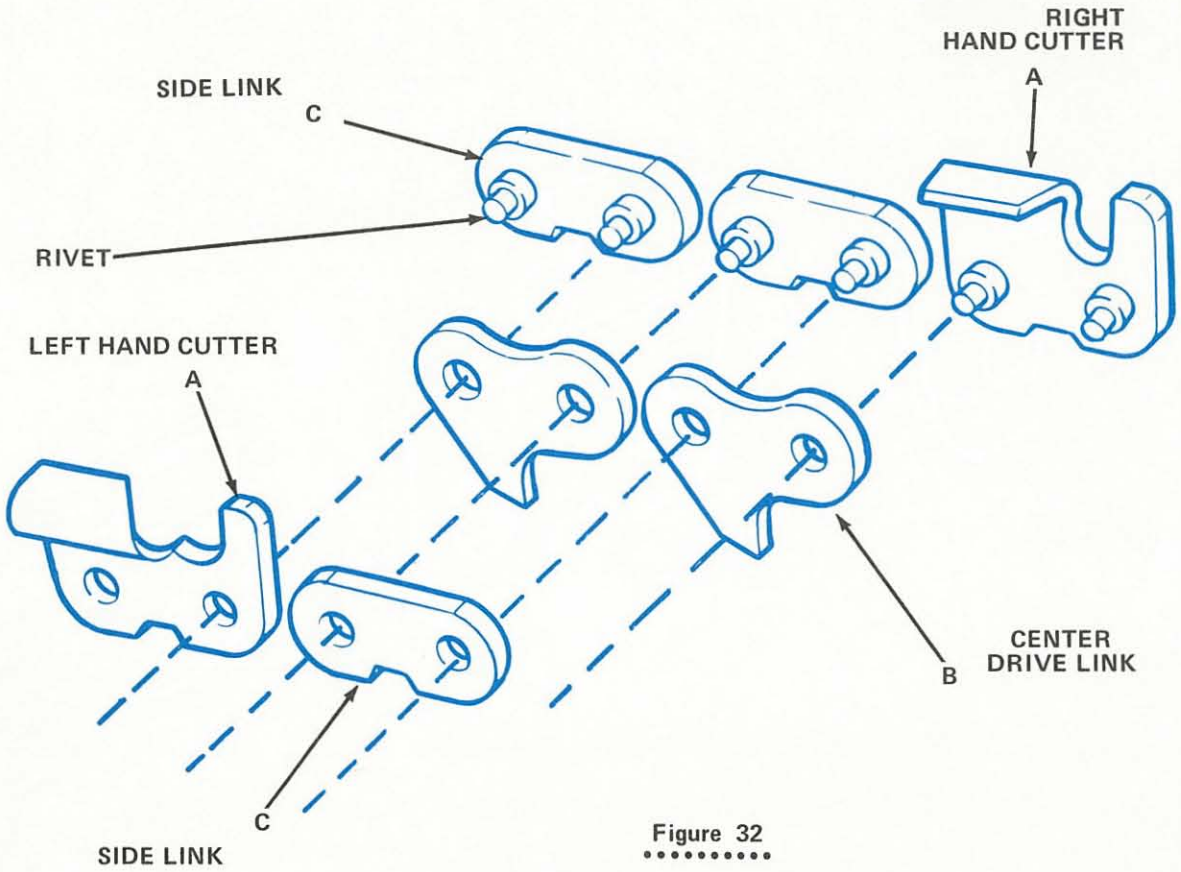


Figure 32

CHAIN CONSTRUCTION

The three parts that make up a saw chain are shown in Figure 32. The cutters shown at A are left and right hand. The drive links shown at B ride in the groove of the guide bar and are driven by the sprocket.

The side links shown at C are used to connect the drive links and the cutters together to form a continuous endless chain. Generally the side links and cutters have rivets preset as shown. Sometimes the rivets may be installed separately.

The dotted lines show the assembly order of these three parts of the chain. Notice how the left and right hand cutters follow each other, alternately cutting one side and then the other. This keeps the chain guided straight. There are several different types of cutters but they all have this same construction.

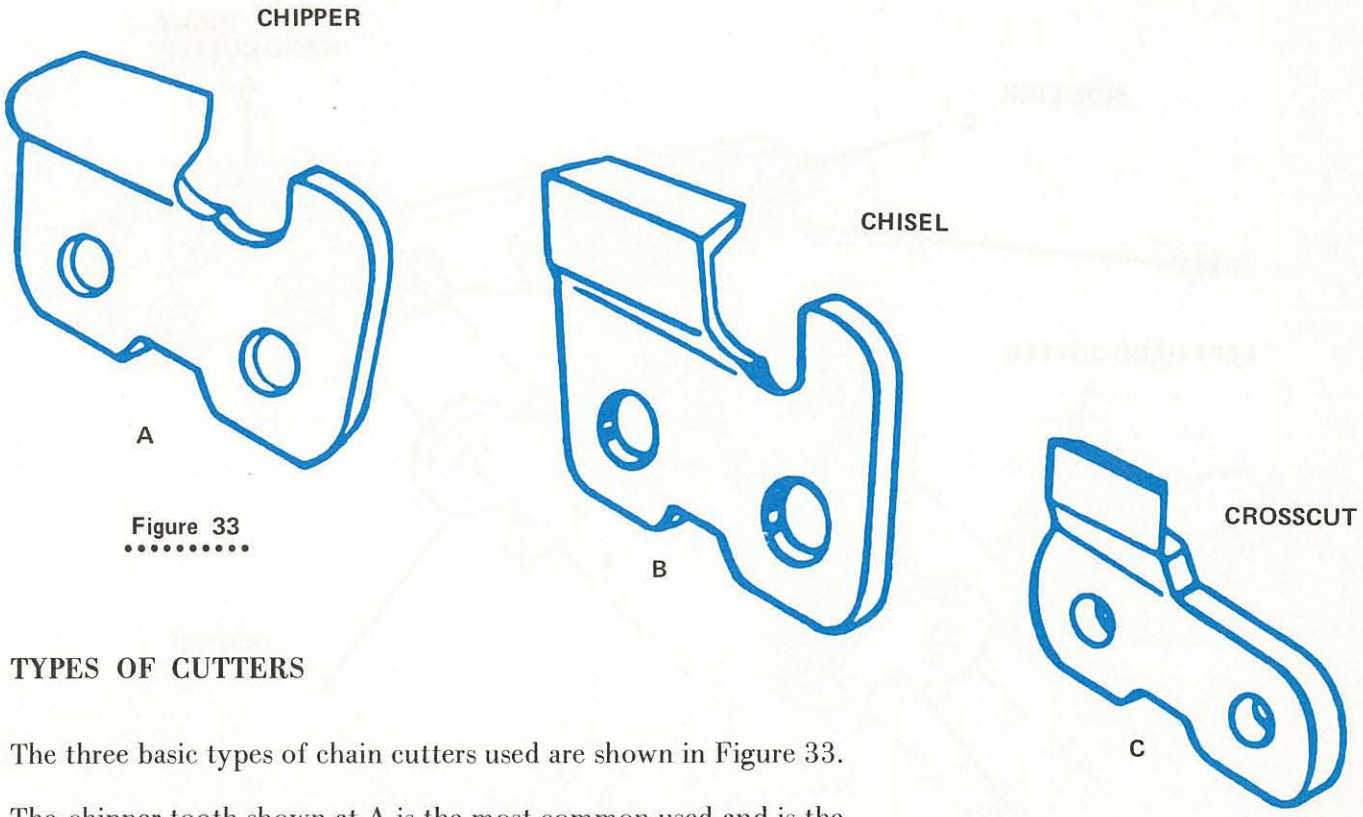


Figure 33

TYPES OF CUTTERS

The three basic types of chain cutters used are shown in Figure 33. The chipper tooth shown at A is the most common used and is the easiest to sharpen. The chisel and crosscut teeth shown at B and C are used by some professional woodsmen for special purpose cutting. The majority of chains for general purpose use will have the chipper tooth.

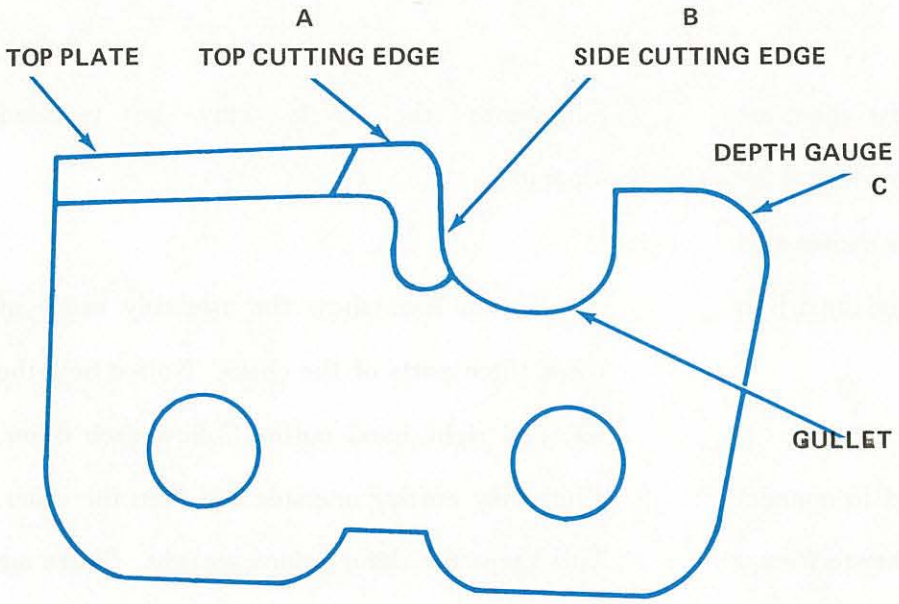


Figure 34

PARTS OF THE CUTTER

The chipper cutter shown in Figure 34 has a top cutting edge at A and a side cutting edge at B. The part shown at C is the depth gauge. This part is just a little lower than the top cutting angle and is used to control the depth of cut made by the cutter.

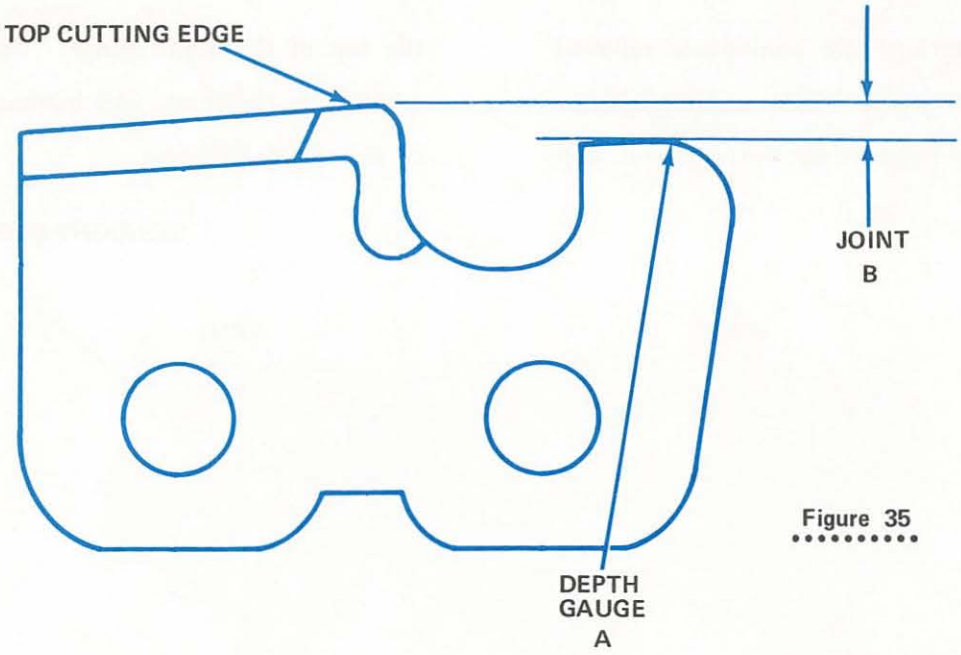


Figure 35

The joint of the chain is shown in Figure 35. The depth gauge at A must be lower than the top cutting edge. The distance shown at B is the joint. The amount of joint will depend on the pitch of the chain and can be from .020 to .060 inch.

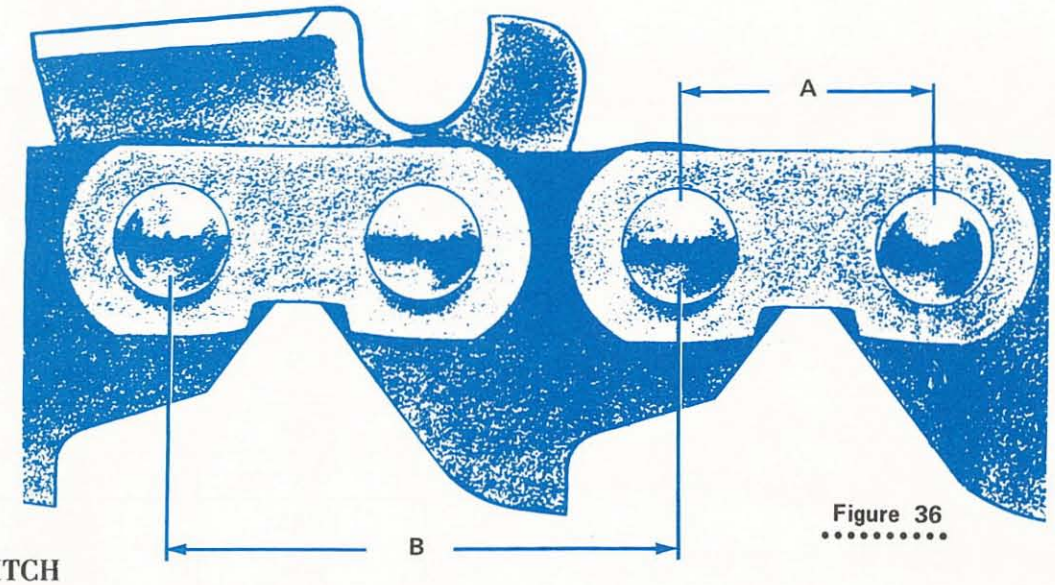


Figure 36

CHAIN PITCH

The pitch of a saw chain must match the pitch of the teeth on the drive sprocket. Pitch is the distance between the centers of the rivets on the chain shown at A in Figure 36. The most accurate way to find the pitch of a chain is to measure the distance between any three rivets next to each other as shown at B. Measure this distance and divide the result by two. As there is a slight difference in the way some chains are made, you cannot always measure between two rivets. If the distance at B measures one inch, the chain would have a 1/2 inch pitch.

DEPTH GAUGE SETTINGS

Depth gauge settings are sometimes referred to as the chain joint. This is the distance between the top edge of the cutting tooth and the top of the depth gauge. The depth gauge setting, or the joint, will increase as the pitch of the chain increases.

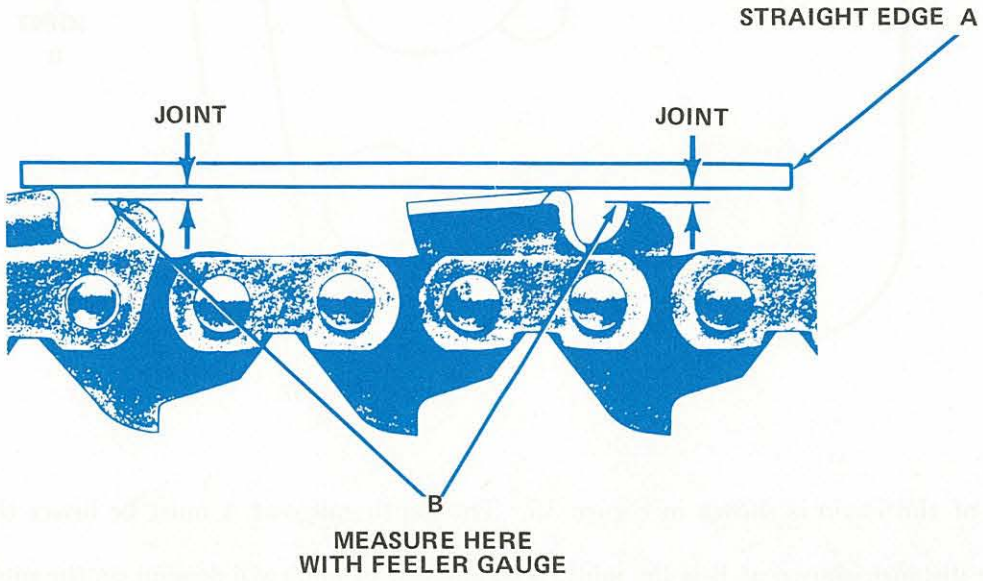


Figure 37

Figure 37 shows the method of checking for proper joint. Use a small straight edge as shown at A that will rest on the top cutting edge of two cutters. Use a feeler gauge to check the distance shown at B.

CHAIN PITCH AND DEPTH GAUGE

The recommended depth gauge setting for different chain pitch is shown in the chart in Figure 38. These depth gauge figures are for general sawing. When sawing frozen or extremely hard woods exclusively, a little less depth clearance can be used. Soft stringy wood requires more clearance.

CHAIN PITCH	DEPTH GAUGE
1/4	.020
21/64	.025
3/8	.025
11/32	.030
7/16	.030
1/2	.030
9/16	.040
5/8	.060
3/4	.060

Figure 38

After the depth gauge has been jointed it cannot be left with a sharp corner. The sharp point must be rounded off as shown in Figure 39. The point shown at A should have a rounded corner to keep the gauges from digging in while the chain is cutting. This is part of the chain sharpening operation which we will cover later.

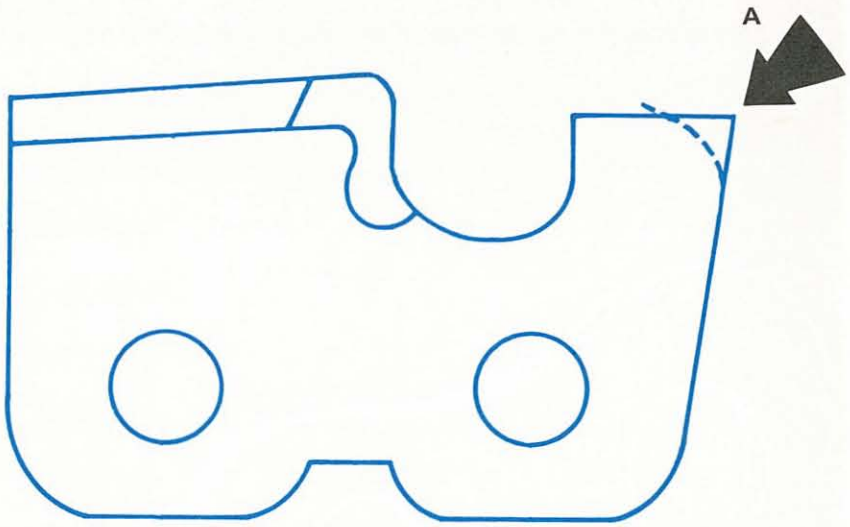
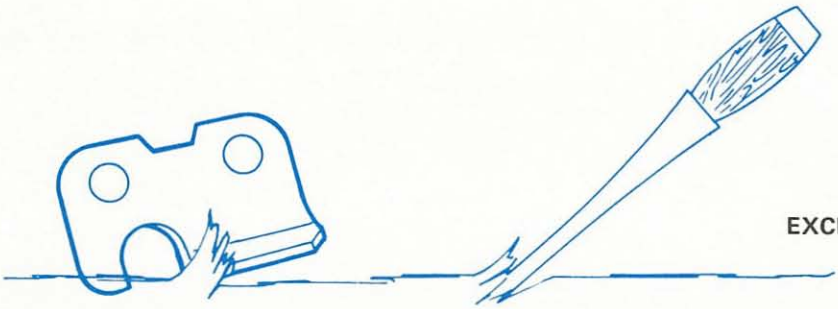


Figure 39



EXCESSIVE JOINT

A

Figure 40

CUTTER ACTION

Chain cutters act like a wood plane. If the angle at which the cutting point hits the wood is correct, the chain will cut a normal chip smoothly and quickly. It will not dig into or kick back from the wood. Excessive joint as shown at A in Figure 40 will cause the cutter to dig into the wood. It is trying to remove too much wood at one time. This is because the joint of the depth gauge is too great.

INSUFFICIENT JOINT

B

A depth gauge with insufficient joint is shown at B. This causes the cutting point of the tooth to skip across the top, removing very little wood. The chips will come out very fine. The chain is not cutting efficiently or at its capacity.

DRIVE LINKS

The drive link is the center link of the chain that is driven by the drive sprocket. In addition to driving the chain, this link also cleans out the bar guide groove. Sawdust will have a tendency to collect and pack in the bar groove. A typical drive link is shown in Figure 41. The point shown at A is sharp and cleans sawdust out of the bar groove. If sawdust is allowed to build up in the bottom of the bar groove the bottom of the drive link shown at B will ride up on it. This will cause the chain to tighten. It will then begin to heat and stretch. This will put the chain out of pitch with the sprocket. It also causes the chain to ride high in the bar groove and cause the chain to weave. This would cause excessive wear on both the chain and the bar groove.

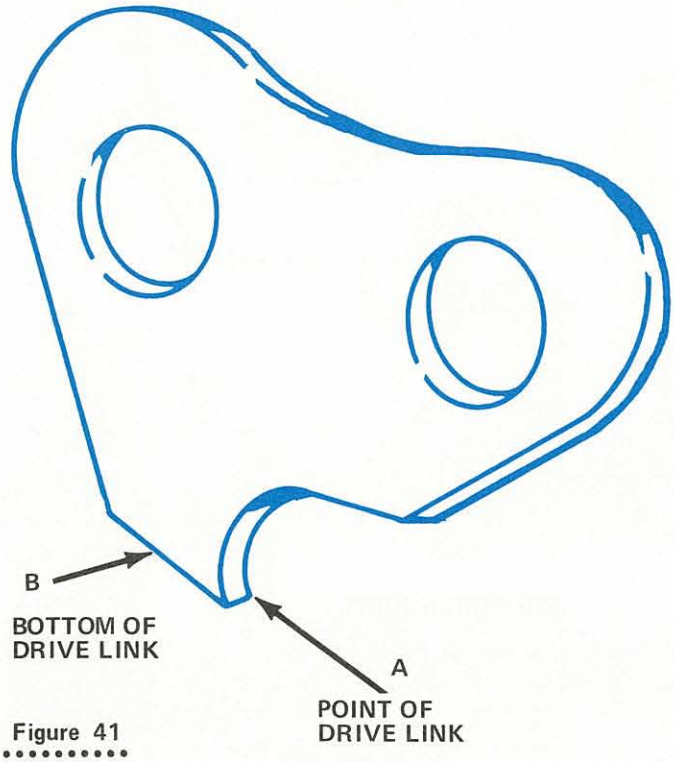


Figure 41

The tang or bottom of the drive link does not actually ride in the bottom of the bar groove. In order to reduce friction, there is a very small space between the tang and bottom of the bar groove as shown in Figure 42. The space shown at A will vary from 1/32 to 1/16 inch depending on the length of the drive tang shown at B.

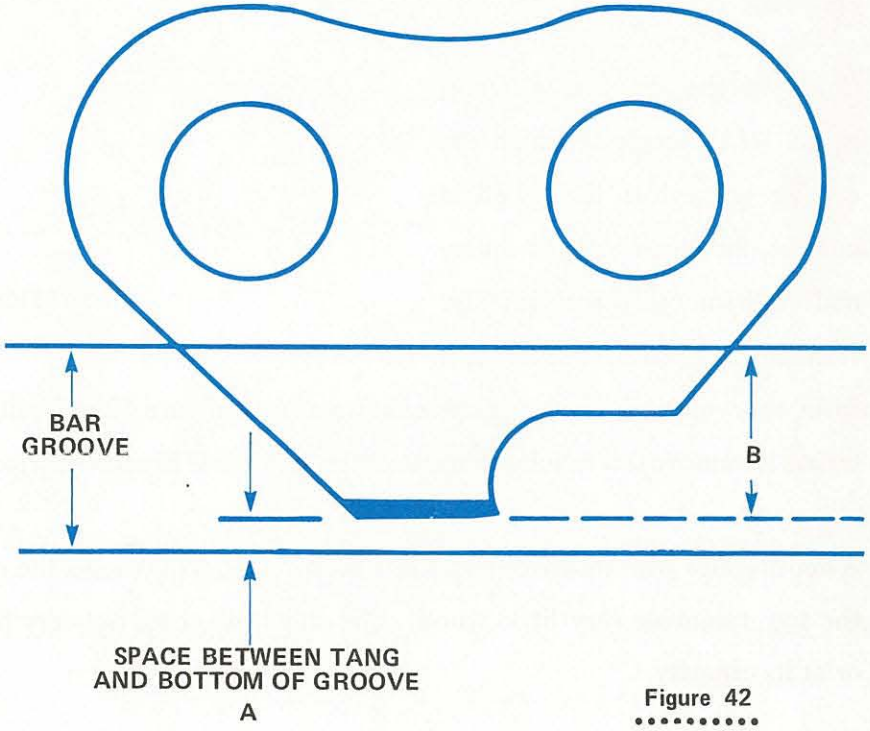
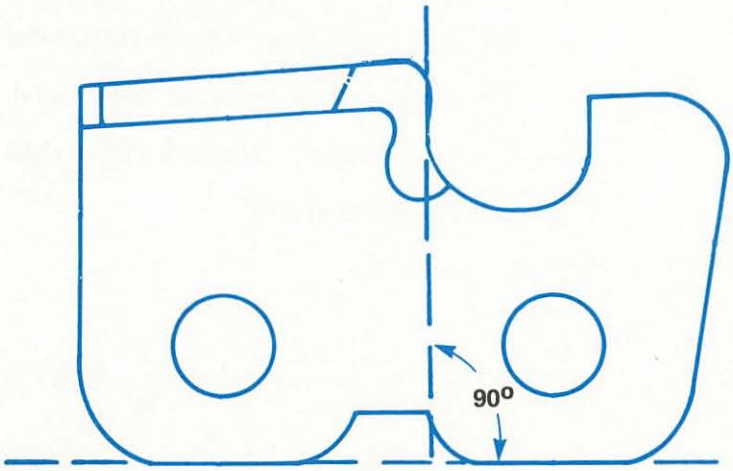


Figure 42

The length of the various drive tangs and the recommended bar groove depth are shown in the chart in Figure 43. When replacing a chain or guide bar the length of the tang and depth of the guide bar slot should be checked. If the top of the guide rail is worn it will allow the tang to ride too deep in the groove.

Length of Drive Link Tang "B" Is:	Bar Groove Depth Should Be At Least:
1/4"	5/16"
17/64"	21/64"
9/32"	11/32"
3/8"	7/16"

Figure 43



SIDE ANGLE

CHIPPER . . . CROSSCUT . . . CHISEL

Figure 44

CUTTING ANGLES

There are two basic angles to consider in the cutting action of a chain saw cutting tooth. Figure 44 shows the side cutting edge at a 90 degree angle to the flat part of the cutter that rides on the edge of the guide bar. This angle is used on most chipper, crosscut and chisel chains. Occasionally manufacturers may recommend angles slightly different but you can generally do a good service job with this side angle.

Figure 45 shows the top cutting angles for the three basic types of cutters. One reason for the cutting angle is to allow the cutting edge to clear out the sawdust as it cuts. The different cutting actions of these three cutters require different top cutting angles for most efficient operation. By far the most popular and widely used on most smaller chain saws is the chipper tooth.

The chisel and crosscut tooth are used more for special applications in the logging and pulpwood industry. Most of the engine and chain saw service work will be with saws having the chipper type tooth.

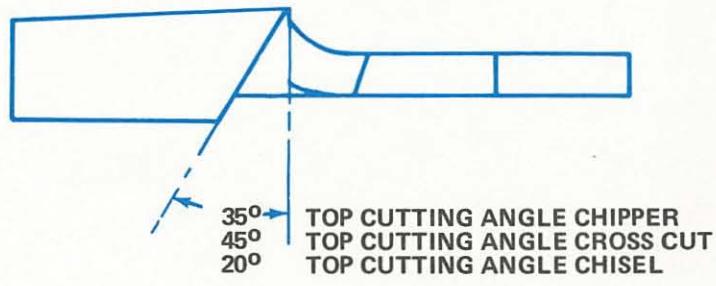
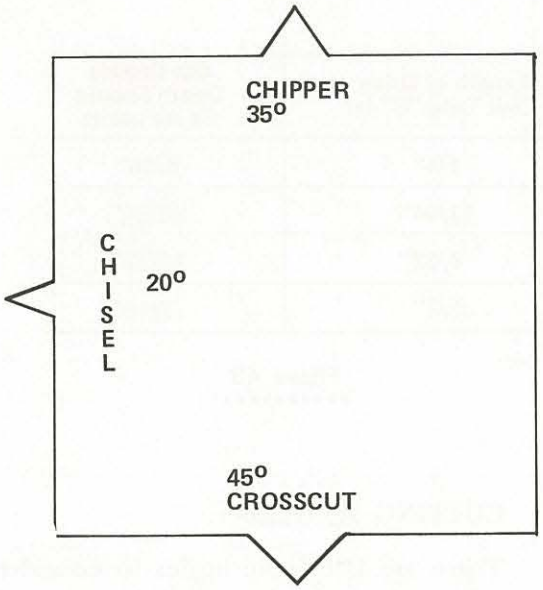


Figure 45



TOP CUTTING ANGLE TEMPLATE

Figure 46

Saw chains may be sharpened by free hand filing, use of a filing guide or ground on a chain saw sharpener, such as the Belsaw Model 550. Figure 46 can be used as a template to make a gauge tool for checking the top cutting angle. Use this template as a guide to transfer the pattern to a piece of thin metal. The guide angles will check either right or left cutting angles.

Figure 47 shows the gauge tool at A placed along side the link. This is a chipper cutter with a 35 degree top angle. The angle of the gauge is 70 degrees. The left side against the cutting angle is 35 degrees and is used for checking the right cutting angle. The other two points on the gauge are for crosscut and chisel cutters.

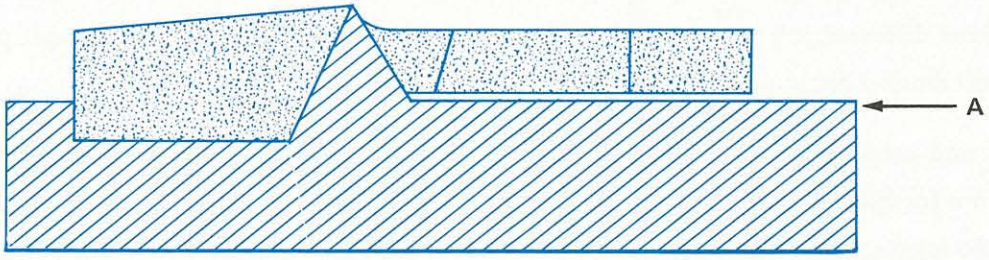
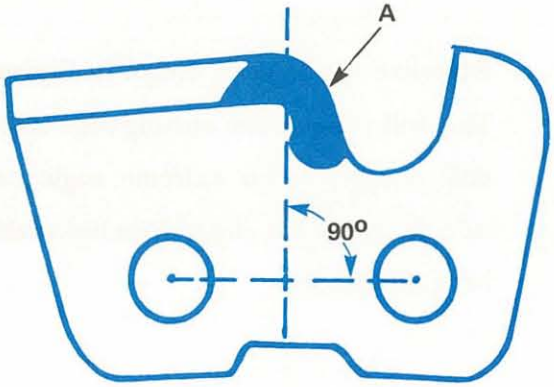
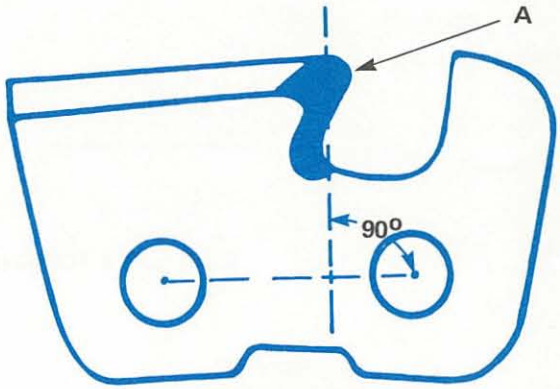


Figure 47



EXCESSIVE BACK SLOPE

Figure 48



EXCESSIVE HOOK

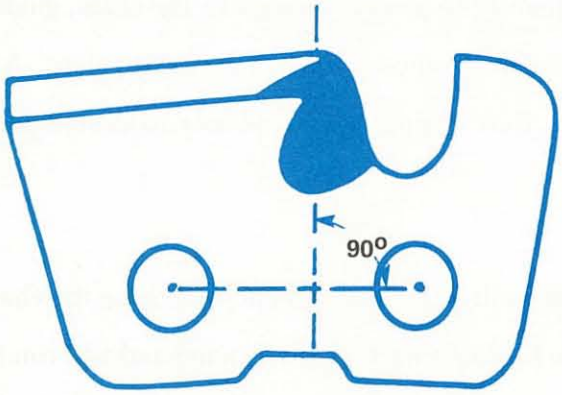
Figure 49

Figure 48 shows a tooth sharpened with too much back slope. This condition will cause extreme wear in the heel area shown at A. The cutters will have a resistance to feeding into the wood.

Figure 50 shows a tooth with too much undercut. The cutting angle is sharpened too thin and will become dull very quick. It will also have a tendency to dig into the wood. This extreme cutting angle gives side thrust to the guide bar and causes excess wear of the guide bar groove.

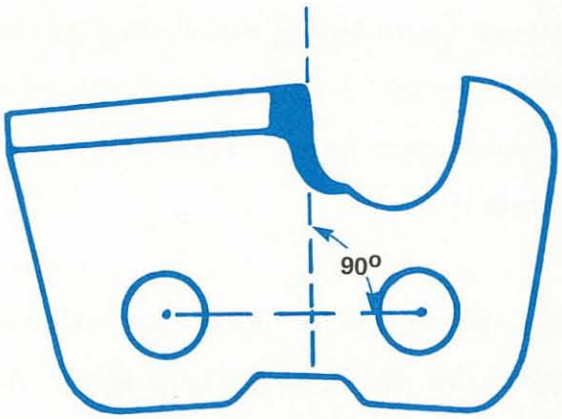
Excessive hook as shown in Figure 49 will cause rapid wear at the heel shown at A. The cutting action of the chain will have a tendency to grab and pull itself into the wood. This causes rapid wear and strain on the guide bar and makes the saw hard to control.

The tooth shown in Figure 51 has the under cut too small. The top cutting edge at A will pound against the wood and cause excess wear on the guide bar and groove.



EXCESSIVE UNDERCUT

Figure 50



UNDERCUT TOO SMALL

Figure 51

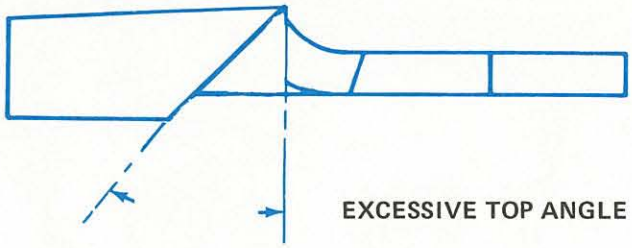


Figure 52

Excessive top angle is shown in Figure 52. This will cause a fine cutting edge that will dull rapidly. This extreme angle causes side thrust on the chain drive links and the bar guide groove.

Figure 53 shows insufficient top angle. It will cause a very rough cut and require considerable more power than necessary. The cutting edges will dull rapidly. Correct cutting angles should be as near as possible to the ones shown in Figure 44 and 45, unless specified by the manufacturer or the operator.

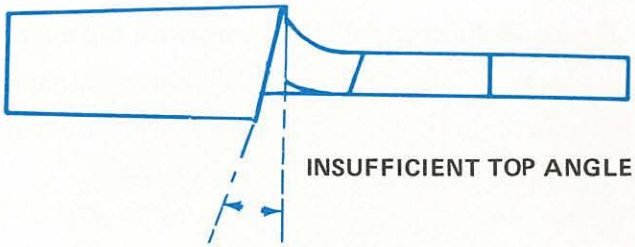


Figure 53

CHAIN TENSION

Chain tension must be properly adjusted and checked frequently to prevent damage to the chain, guide bar and drive sprocket. A chain running too loose or tight will damage these parts in a very short time. A new chain requires more frequent adjustment than an old one. New chains have a tendency to stretch until all parts break in.

A chain will have a different tension when it is cold. Metal contracts when cold and will cause the chain to become smaller and fit the guide bar tighter. As the chain becomes warm it will expand and will run loose on the bar. For this reason chain tension should always be checked when the chain is cold. If tension is checked when the chain is warm it will become too tight when the chain cools and shrinks.

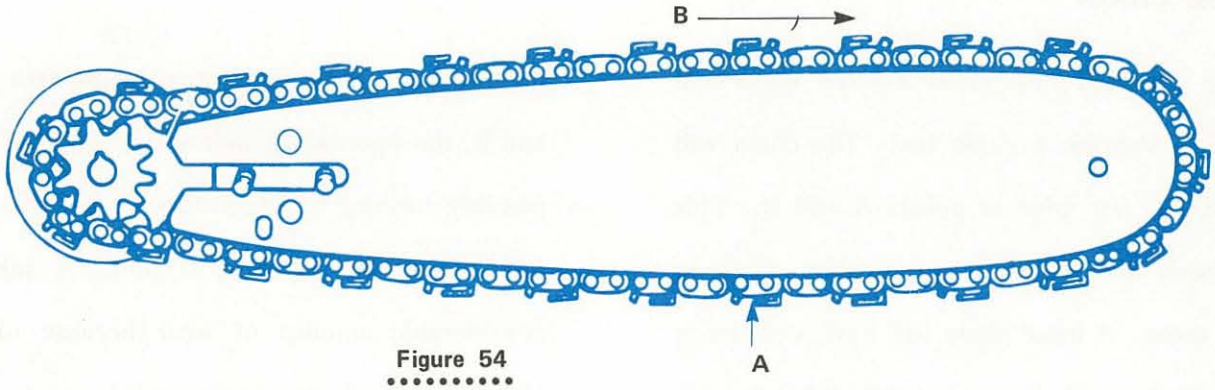


Figure 54

Figure 54 shows the first step in checking chain tension. Pull down on the chain about midway as shown at point A. With a slight amount of pull you should be able to pull the chain down about 1/4 inch away from the edge of the bar. You should be able to see the bottom part of the drive link tang.

The chain should be loose enough to pull it around by hand in the direction of the arrow at B. *Caution:* Always use gloves or a shop rag to protect your hands.

Chain tension should be checked carefully before any sawing is done and should be checked during a days work, particularly if a new chain is being used.

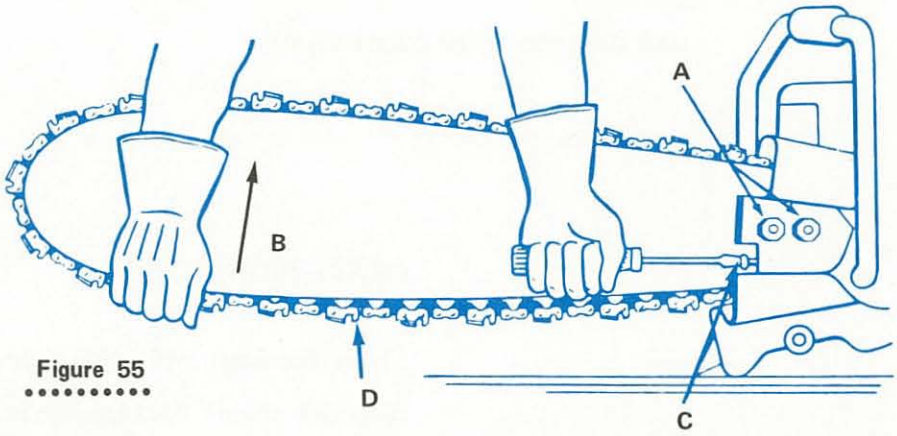


Figure 55

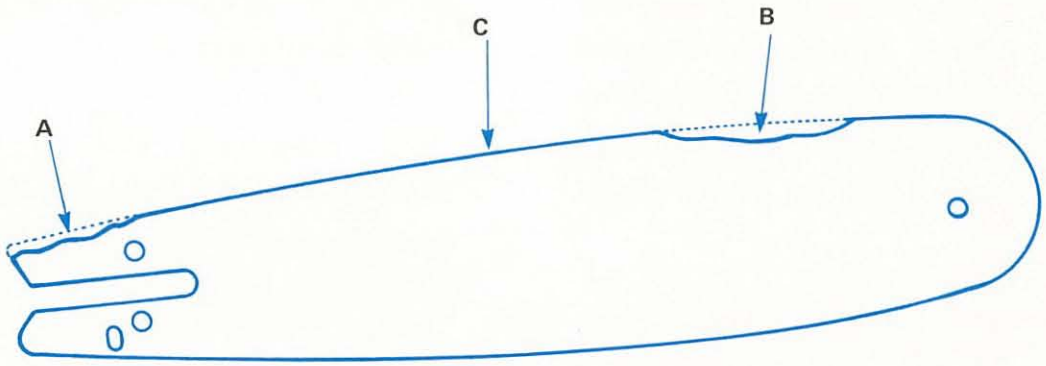
CHAIN ADJUSTMENT

The chain guide bar has a slot in it for adjustment to compensate for chain wear and stretch. First, loosen the two hex nuts shown at A in Figure 55. Lift up on the bottom of the chain and bar as shown at B. Retighten the hex nuts A so they are just finger tight. Hold the bar in this position. This takes up any play between the guide bar slots and the mounting studs. Using a medium size screwdriver, turn the adjusting screw C until the drive link tangs barely enter the bar guide groove.

Pull down on the chain at point D to take up all slack around the bar. Release the chain and turn the adjusting screw until the tang once more barely enters the bar groove. Tighten both hex nuts A to secure in position. *CAUTION:* Before checking tension or making chain adjustment be sure chain is well oiled.

LOOSE CHAIN

Figure 56 shows the areas a loose chain will begin to damage a guide bar. The chain will pound the bar edge at points A and B. This will cause the bar to begin breaking down in these areas. A loose chain will have a tendency to jump the guide bar at point C. When a guide bar begins to show slight wear in the area of A and B, the operator should be warned that he is possibly running the chain too loose. This may not always be the case as point A takes a considerable amount of wear because of the chain entering the bar groove at this point.



BAR DAMAGE FROM LOOSE CHAIN

Figure 56

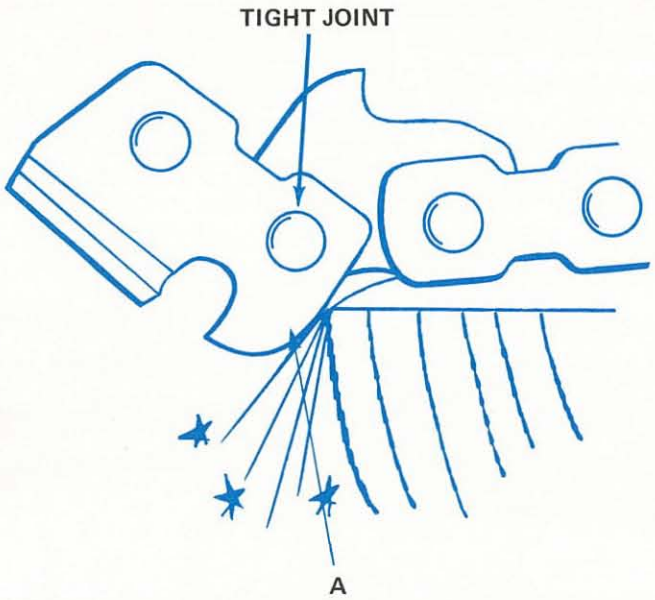


Figure 57

CHAIN BREAKAGE

Chain breakage will seldom be the result of a defective chain. This trouble is generally caused from excessive strain. Tight joints caused from inadequate lubrication or rust, may cause a cutter to become cocked as shown in Figure 57. The depth gauge shown at A will strike the wood as the tooth begins to enter the kerf. This will kick the cutter up and can throw enough strain on the chain to break it.

If the drive links or side links strike the bar as shown in Figure 58 it can cause chain breakage. This can be caused from the chain being too loose or the sprocket not matching the chain pitch. Either the sprocket or the chain can be worn so one is out of pitch with the other. This condition is generally caused from the front of the bar not having a groove wider at the entrance to receive the chain.

Chain breakage can also be caused from insufficient depth gauge clearance, drive links riding the bottom of a bar groove that is too shallow, or excessive back slope of the cutter.

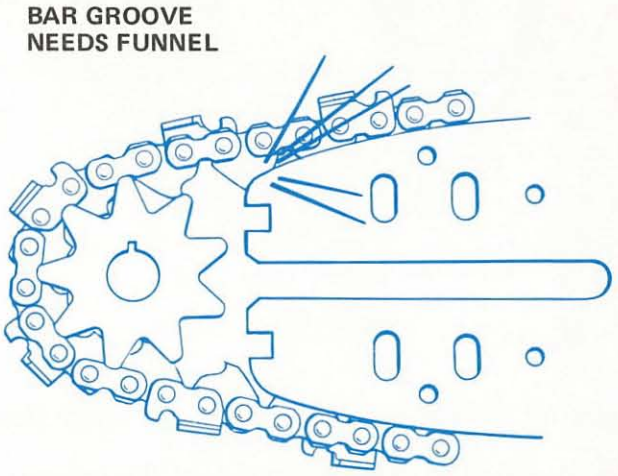


Figure 58

CHAIN DRIVE LINK DAMAGE AND CAUSES

Figure 59 shows the drive link worn flat on the bottom. If the tang shown at A is worn flat, the bar groove is too shallow along the length of the cutter bar. This allows the tang to ride on the bottom of the bar groove. Instead of the bottoms of the links the cutters will be riding on the edge of the bar. To correct this condition the bar groove must be reground or a new one installed. It is generally best to replace the bar since very few shops are equipped for regrinding.

If the drive link is curved at the bottom as shown at A in Figure 60 it is caused by the bar groove being too shallow at the nose of the cutter bar. The tang will ride the shallow bar groove nose every time it goes around. To correct this condition the bar groove must be reground or replaced with a new cutter bar.

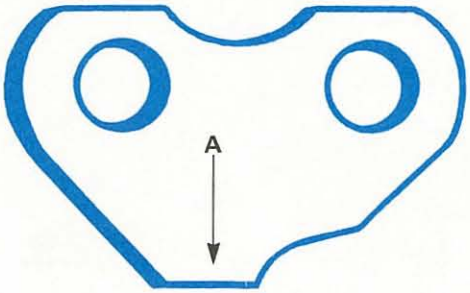


Figure 59

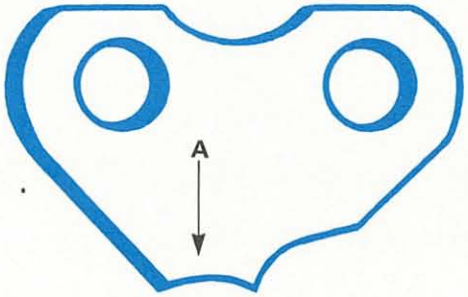


Figure 60

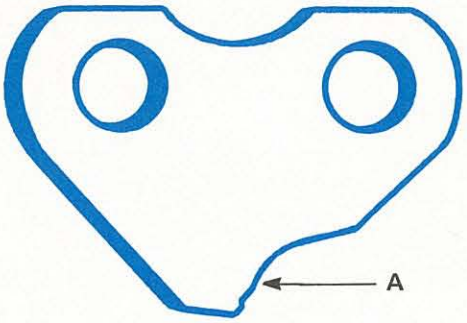


Figure 61

Figure 61 shows the tang of the drive link worn at point A. This condition is caused by the tang striking the bottom of the bar groove as the chain leaves the sprocket and enters the bar. This is caused by the chain being loose and entering the bar groove high or the funneling at the entrance to the bar groove is not adequate and will have to be filed out.

Figure 62 shows damage that can occur to the front of the side links or cutters. The worn shoulder shown at A is caused by striking the rails at the entrance to the cutter bar. This condition can be corrected by beveling the groove at the point the chain enters the cutter bar.

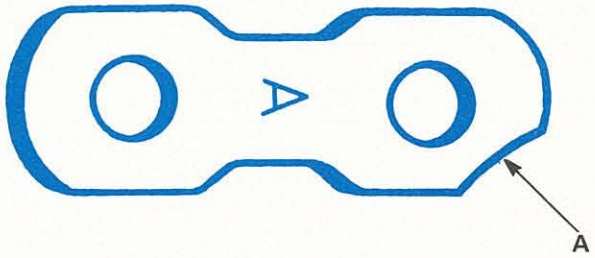


Figure 62

Figure 63 shows the drive tang nicked and battered at point A. This is caused by a damaged or wrong sized sprocket. The drive tang is designed to fit down in the bottom of the sprocket and not ride up the shoulder as shown at B. This causes the drive tang to break down very rapidly. A new sprocket of the correct size to match the chain is required to correct this condition.

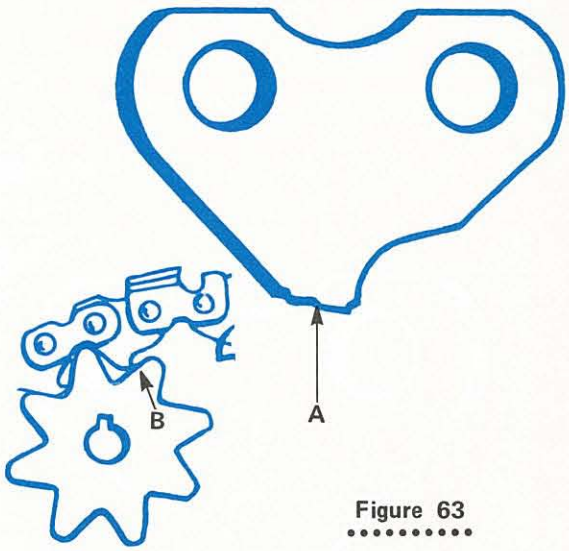


Figure 63

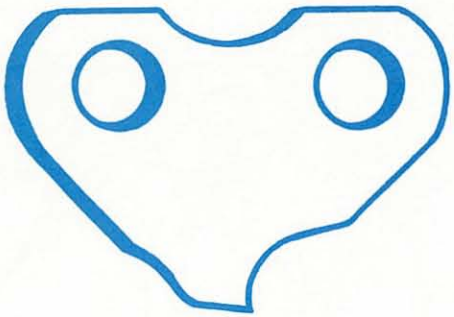


Figure 64

When the back of the tang length is rounded, nicked or peaned as shown in Figure 64, it is caused by the sprocket being undersized or it has grooves worn in it. A new sprocket is necessary to correct this condition.

Figure 65 shows what happens when the tang hits the bottom of the sprocket. If the sprocket pitch is not deep enough, the tang will hit the bottom and pound the lip as shown at A. A new sprocket to fit the chain pitch is necessary to correct this condition.

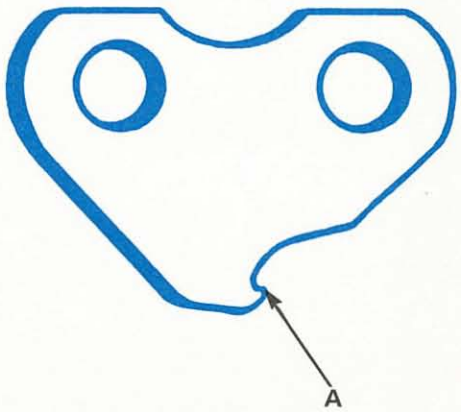


Figure 65

Figure 66 shows the tang damaged in both the front and back. Both points A and B show damage. This can be caused from improper shape or fit of the sprocket teeth. Often it is caused from a loose chain that will chatter. Correct this condition by either replacing the sprocket or checking the chain tension.

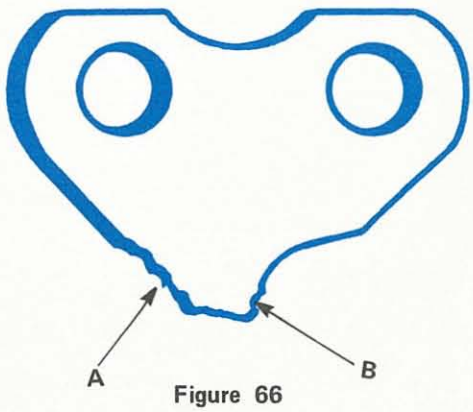


Figure 66

CRACKED CUTTERS AND SIDE LINKS

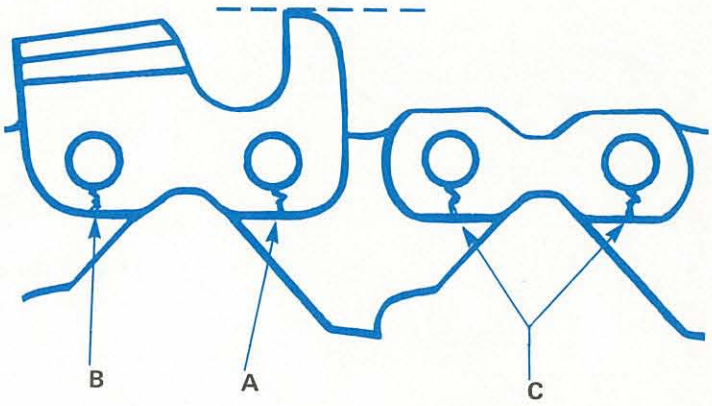


Figure 67

Cracks under the front rivet of the cutter as shown at A in Figure 67 are caused by the depth gauge being too high. The depth gauge drags against the wood and throws excessive strain on the rivet causing the crack at A. Cracks under the rear rivet shown at B are caused by the cutter being dull which throws a heavy strain on the rear rivet. If cracks are present under both rivets of the cutter the cause is a combination of the depth gauge being too high and a dull cutter. Cracks under both the cutter and the side link rivets are caused by a tight chain combined with dull cutters and/or high depth gauges. These conditions can be corrected with proper sharpening and replacement of all cracked cutters and side links.

REPAIRING CHAINS

Individual cutters, drive links and side links can be replaced in a saw chain. Rivets are removed with a chain breaker as shown in Figure 68. New parts must be of the same design and pitch as the ones removed. The chain rivets to be removed are placed over the anvil shown at A. When you strike the punch B the old rivet is forced through the chain and into a hole in the anvil. There are several variations in the design of tools for removing rivets. Some use a hand operated tool similar to a pair of vise grips and others are a simple anvil with a punch similar to a nail setting punch.

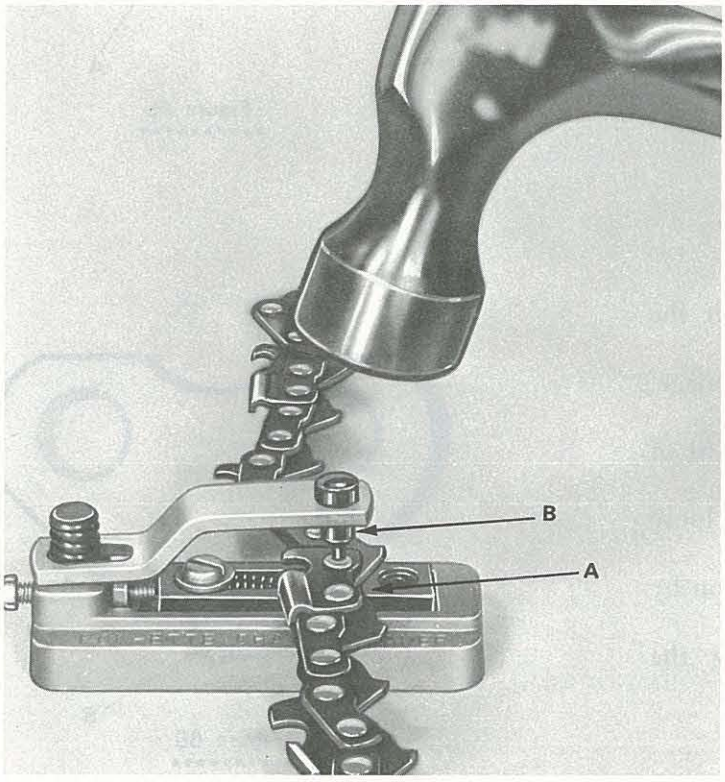


Figure 68

The rivet holes in the outside links are countersunk on one side only as shown in Figure 69. The tie strap shown at A is countersunk on the outside and flat on the inside. The drive link B is flat on both sides. Both of the countersunk holes must face the outside. Most chain breaking tools have a second anvil used to set the rivet after it has been installed. Use the round end of a ball peen hammer for setting the rivet.

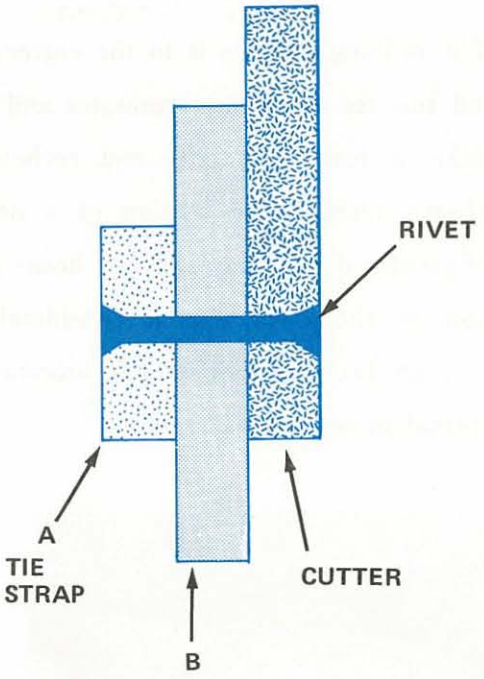


Figure 69

Before installing a new tie strap, cutter or raker on an old chain it will be necessary to file or grind off some of the bottom section that rides on the guide bar or in the bar groove. The new link must have the same dimensions as the old ones in the chain.

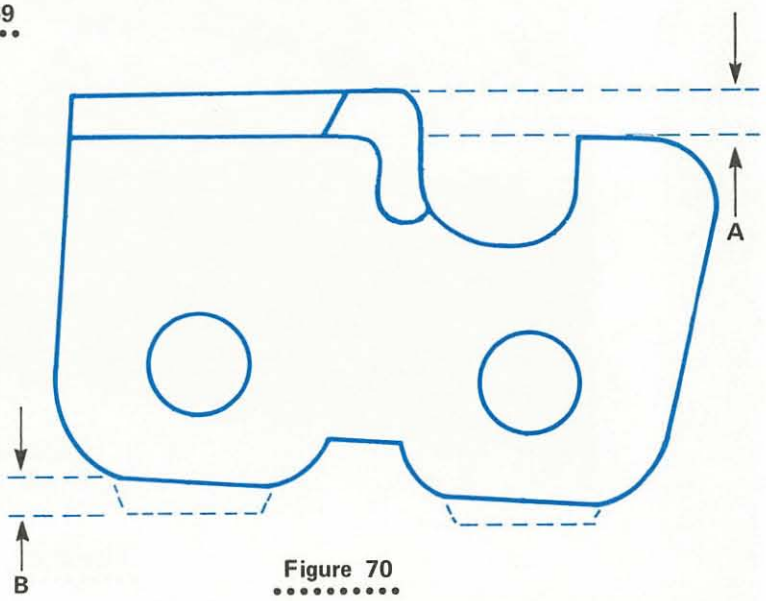


Figure 70

Figure 70 shows the areas that have to be ground or filed when installing a new link. The raker of the cutter shown at A must be lowered so it is the same depth as the other rakers. The cutting edge of the tooth must also be sharpened down so it is the same as the other cutters.

The bottom part of the cutter, tie strap and the raker shown at B must be filed or ground back to the same dimension as the other parts of the chain.

Caution: When installing rivets use light blows to peen the rivet. Do not crush or flatten the rivet or it will result in a crack or tight joint. Check chain to be sure all joints work free.

NEW CHAINS

Always soak a new chain in a pan of oil before using it. Use plenty of oil during the break-in period.

Adjust the chain tension so you can just pull the chain around the bar easily by hand. Start the engine and run the chain slowly for a minute or two. Stop the engine and check the chain tension. If it is loose, tighten it to the correct tension and run for a few more minutes and recheck. Make a few light cuts and recheck again. Always recheck the tension of a new chain frequently during the first few hours of operation as they will stretch considerably until they are broken in. Use more lubrication than normal on new chains.

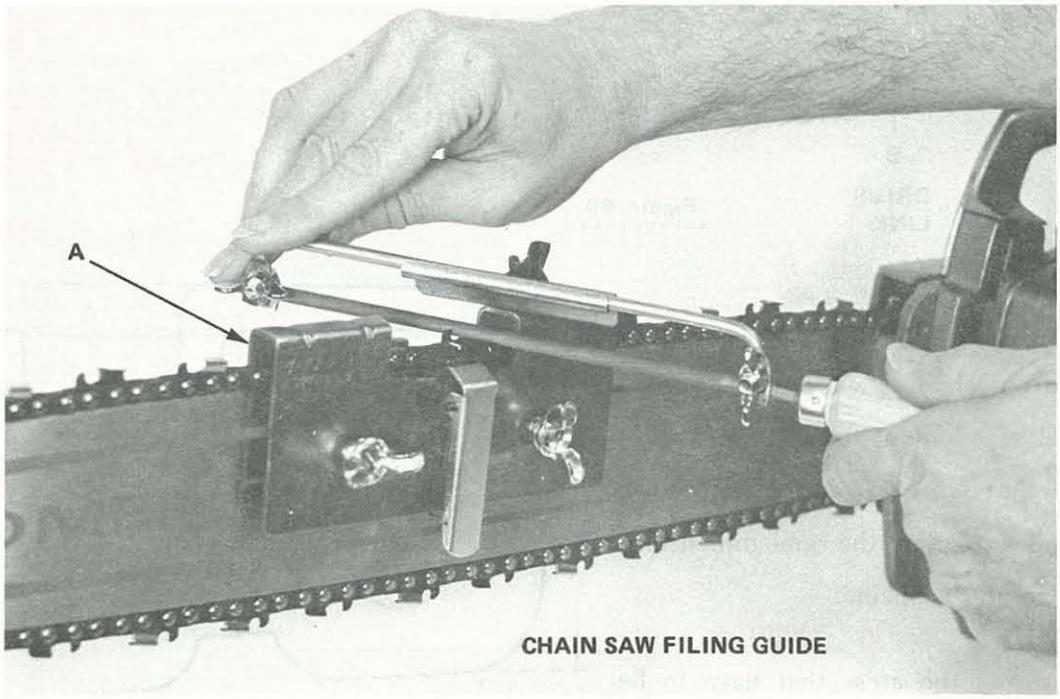


Figure 71

FILING CHAIN CUTTERS

There are two methods used for sharpening chains. Most field operations and some small shops sharpen chains by hand filing with a filing guide to insure the correct cutting angle. Others use chain saw grinders, such as the Belsaw 550 which we will cover later.

A typical chain saw filing guide is shown in Figure 71. The guide channel shown at A fits over the top of the chain cutters. The file holder can be moved left or right and locked in place at the proper filing angle. The guide also has a height adjustment that allows the file to contact the cutter at the proper depth.

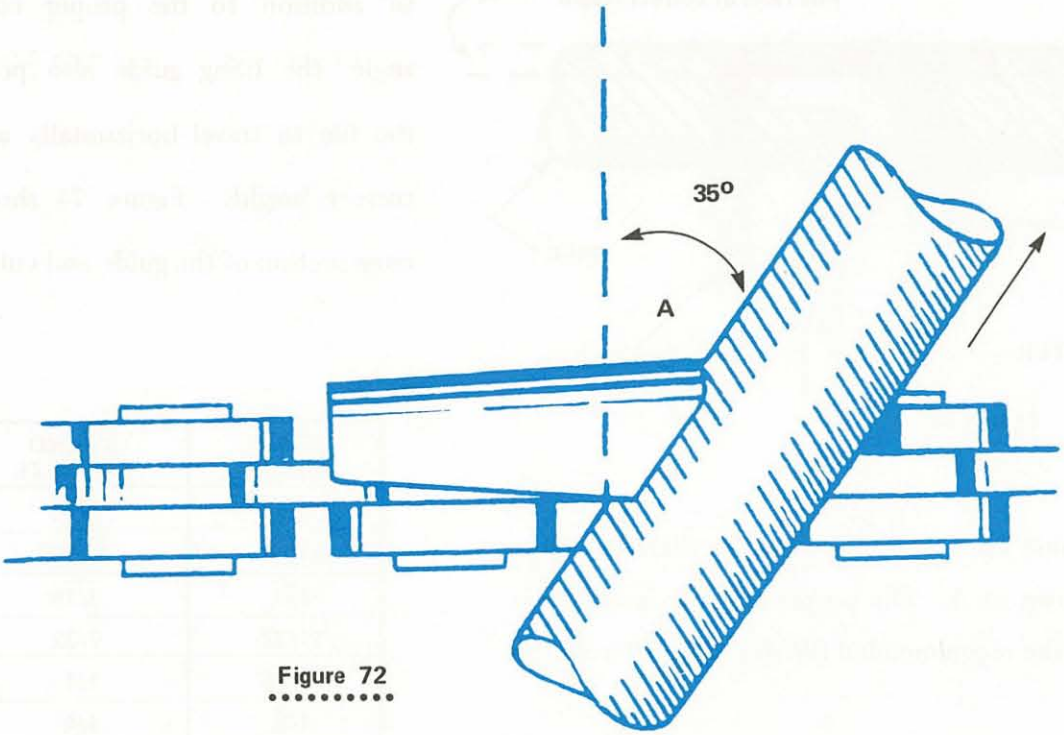


Figure 72

The basic principle of the chain saw filing guide is shown in Figure 72. The proper filing angle for the chipper tooth cutter is shown at A. The file must contact the cutting face at this angle. Every tooth with the angle pointing to the right should be filed with this angle. Every alternate cutter should be filed at this same angle in the opposite direction. The diameter of the file used to file chipper cutters is directly related to the pitch of the chain which will be covered later.

The file guide shown in Figure 73 consists of two basic parts. The channel shown at A fits over the top of the chain and bar. The center disc shown at B can be rotated either left or right and locked in place at the proper angle with the thumb screw C. Once the file is set for filing either left or right cutters do not change the setting until all of the cutters of one hand, either left or right, have been filed.

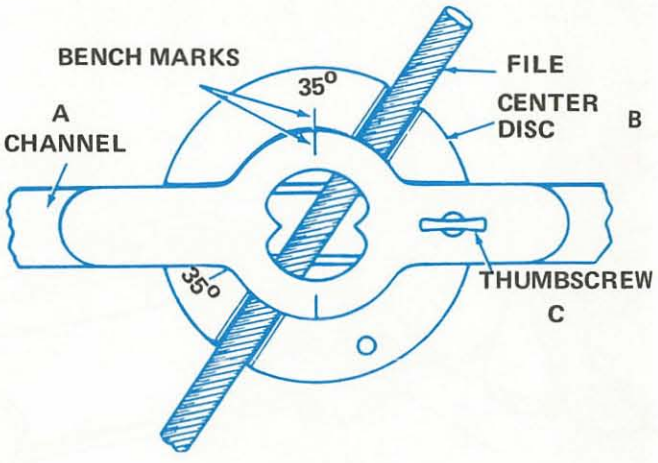


Figure 73

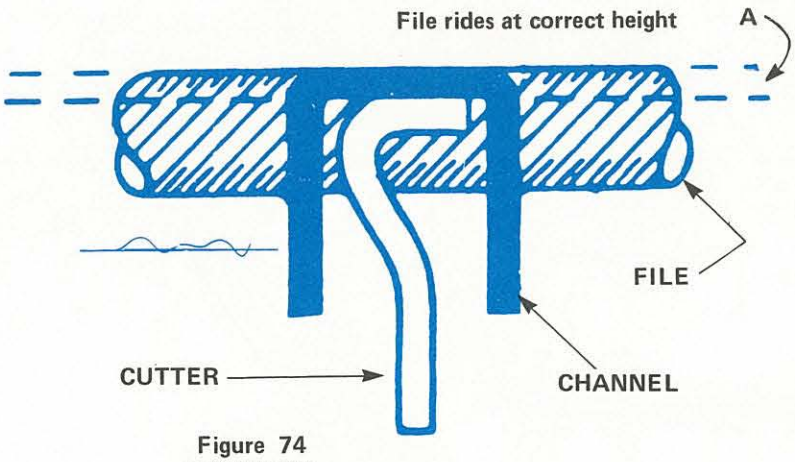


Figure 74

In addition to the proper cutting angle, the filing guide also permits the file to travel horizontally at the correct height. Figure 74 shows a cross section of the guide and cutter.

The file should have from 1/5 to 1/10 of it's diameter above the cutter as shown at A. The proper size file insures this. Figure 75 shows the recommended file sizes for different size chain pitch.

The 3/16 and 1/4 inch round files will sharpen the majority of chains in general use. It is seldom necessary to stock more than just a few of the smaller and larger diameter files.

CHAIN PITCH	ROUND FILE SIZE
1/4	3/16
21/64	3/16
3/8	3/16
11/32	7/32
7/16	1/4
1/2	1/4
9/16	9/32
5/8	9/32
3/4	5/16

Figure 75

Chains can either be sharpened on the saw bar or in a chain filing vise. Before installing the guide make one or two strokes with the file to clean out the gullet between the cutting edge and depth gauge of each tooth. With the guide set at the correct angle, insert the file in the guide as shown in Figure 76. File with firm forward strokes, rotating the file with each stroke. Use approximately the same number of strokes with each cutter. Too much filing will feather the cutting edge. Do not file on the back stroke. File in the direction of the arrow in Figure 72.

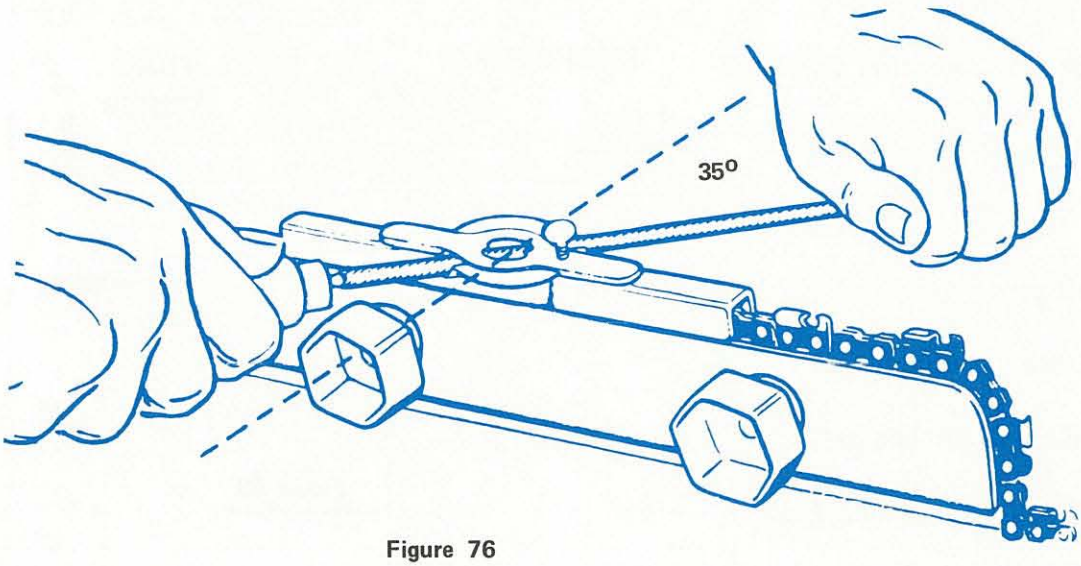


Figure 76

After filing cutter number 1, file cutters 3, 5, 7 and 9 as shown in Figure 77. Continue moving around the chain until all cutters of the same angle have been filed. If you are using a filing vise, turn the chain around and reset the holder to the opposite direction. If filing on the saw bar, reset the angle in the opposite direction and move the guide to the other side of the bar so you will still be filing away from the cutting point.

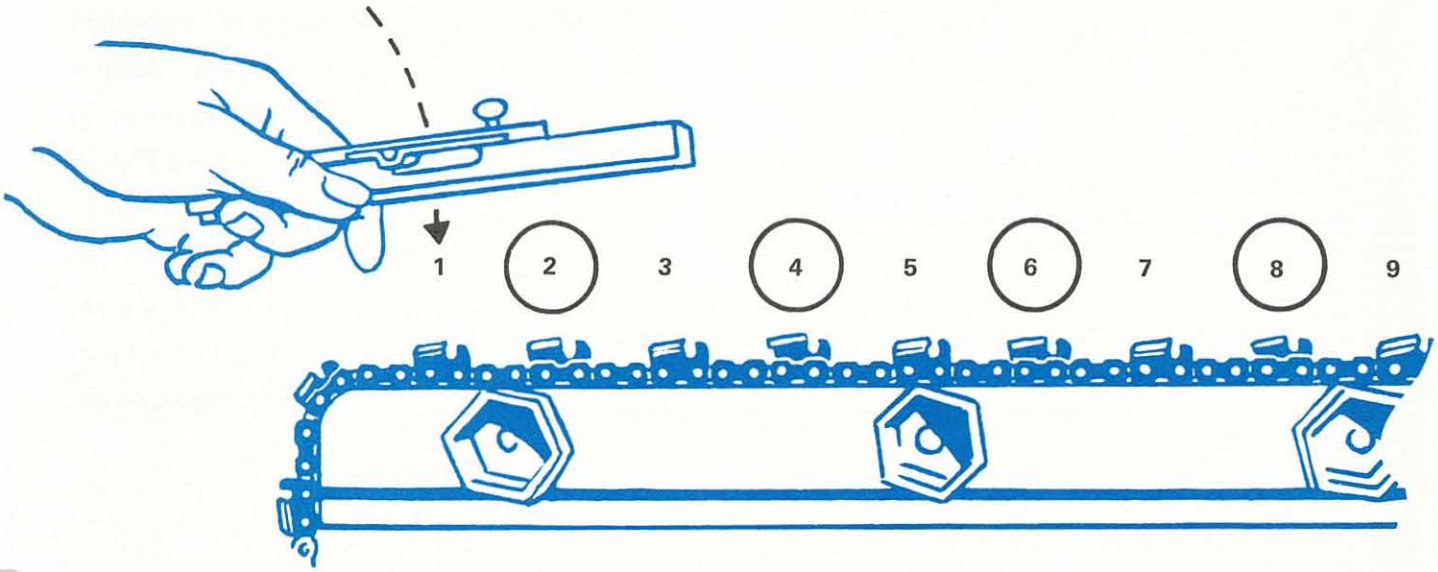


Figure 77

FILING DEPTH GAUGES

Depth gauge setting is very important for efficient chain operation. If the depth gauges are too low they will cause the chain to grab or hang up. If they are too high the chain cutting ability will be reduced and it will produce powder instead of chips. It also increases friction and wear on the guide bar. Recommended depth gauge settings were given in Figure 38. One of the leading chain manufacturers recommends from .025 to .040 inch as shown at A in Figure 78. Soft and stringy woods require about .040 and harder woods less. A straight edge shown at B can be used to level the tops of the cutters and a feeler gauge can be used to measure the clearance of the depth gauge.

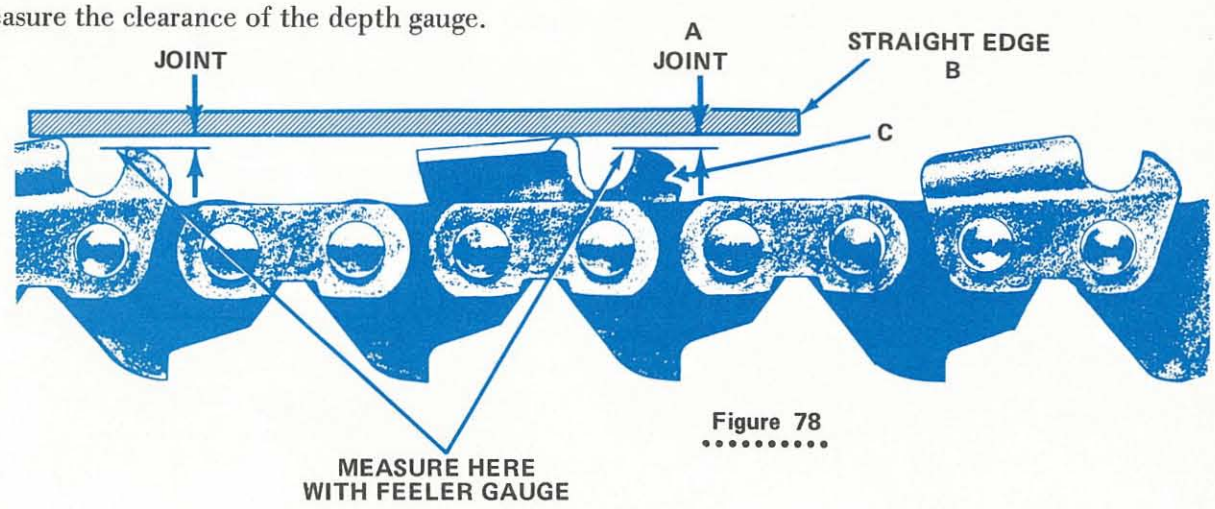


Figure 78

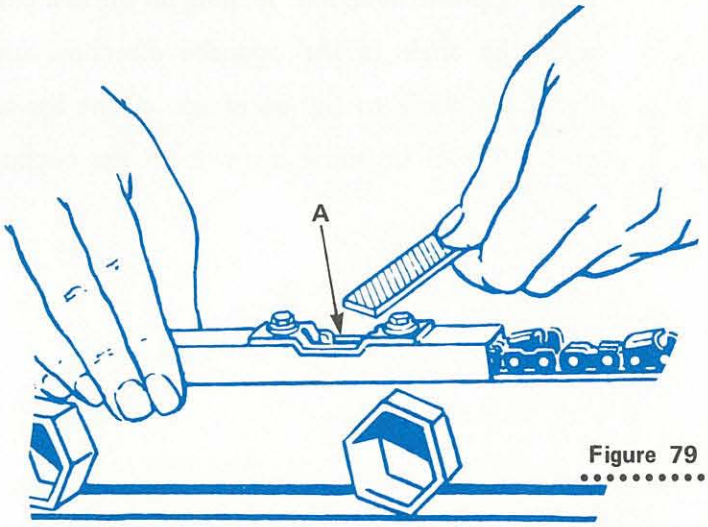
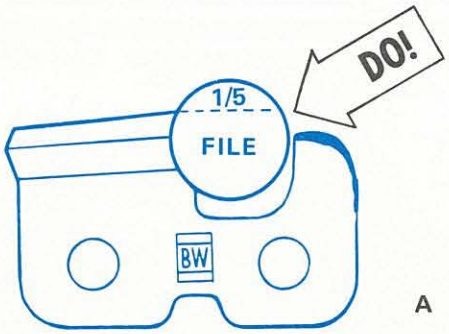
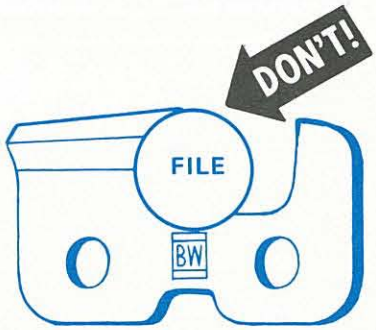


Figure 79

After filing down the depth gauge to the proper clearance be sure to round off the back of the heel shown at C. After sharpening the cutters, the depth gauges must be checked for clearance and adjusted either by using a feeler gauge or a depth gauge tool as shown in Figure 79. This tool is adjustable for different depth gauge settings, generally from .018 to .045 inch. Set the depth gauge tool to the desired depth and lay it over the cutters as shown. The depth gauges should be visible, one at a time, through the slot as shown at A. If the depth gauge raises above the level of the slot, file away the top part until it is down even with the tool. Then remove the tool and round off the forward edge of the depth gauge.



A



B

CORRECT AND INCORRECT FILING

Hold the file so that approximately 1/5 of the file diameter is above the cutting edge of the chisel as shown at A in Figure 80. Filing at this angle will produce the correct amount of hook for best cutting.

Don't hold the file too low as shown at B. This causes too much hook and produces a weak, feathered edge that grabs and dulls very quickly. If the file diameter is too small this condition will generally exist.

Don't hold the file too high as shown at C. This condition produces a flat blunt edge that won't cut chips. It will gouge and fight the wood. This requires excessive pressure on the bar and will cause wear on the chain and bar.

C

Figure 80

Use a round file of the proper size to remove the burrs and ragged edges from the gullet after sharpening as shown in Figure 81. Keep the gullets clean and smooth.

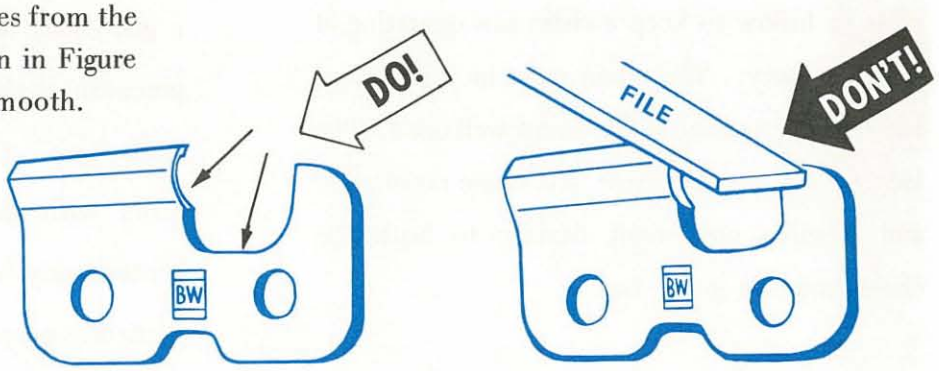


Figure 81

Check the height and shape of each depth gauge as shown at A in Figure 82. Too much depth gauge clearance will cause the saw to grab or stall. Not enough clearance reduces the cutting ability. Be sure to keep the corner well rounded so it will not dig into the wood.

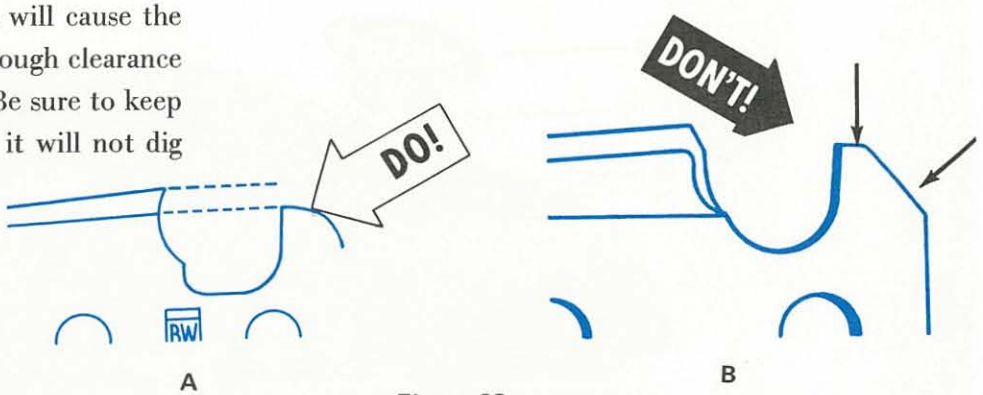
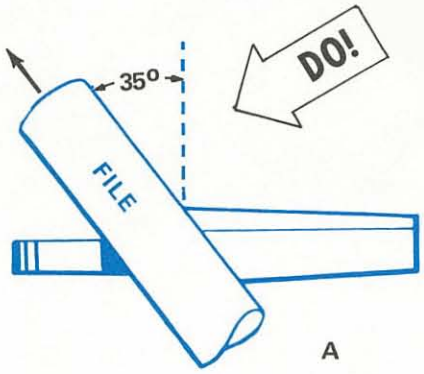


Figure 82



Don't file the top of the depth gauge to a point as shown at B. Compare the shape with a new chisel and maintain the same profile as near as possible. When filing chipper teeth hold the file at a 35 degree angle as shown at A in Figure 83. File with a long forward stroke toward the outside of the chisel. Apply filing pressure sideways, never down. Do not file on the return stroke. Always push a file forward, never pull back. File right and left chisels alike to assure a true running, smooth cutting saw.

Never allow the file to wobble from side to side as shown at B. This produces a rounded cutting edge.

Don't allow the file to ride up and down as shown at C. The use of a filing guide will prevent these common filing errors.

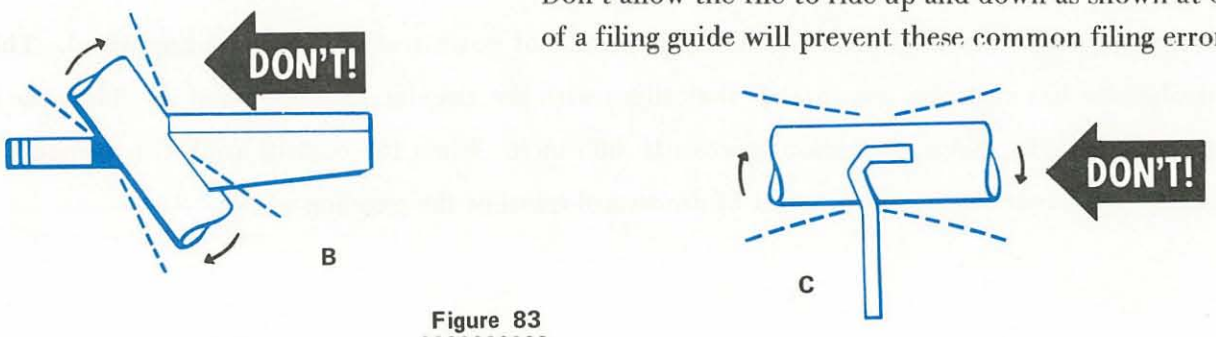


Figure 83

Chain saw manufacturers stress three simple rules to follow to keep a chain saw operating at top efficiency. The chain must be kept sharp, have proper tension and be kept well oiled. The lack of any one of these will cause rapid wear and possible permanent damage to both the chain and the guide bar.

Even though many chains are filed by hand or with the help of a chain filing guide, it is always a good idea to have the chain sharpened on a precision chain grinder at least every fifth or sixth time. Chains will cut much easier and faster with less power if they are sharpened continuously on a machine designed for this particular purpose, such as the Model 550 Chain Saw Grinder shown in Figure 84.

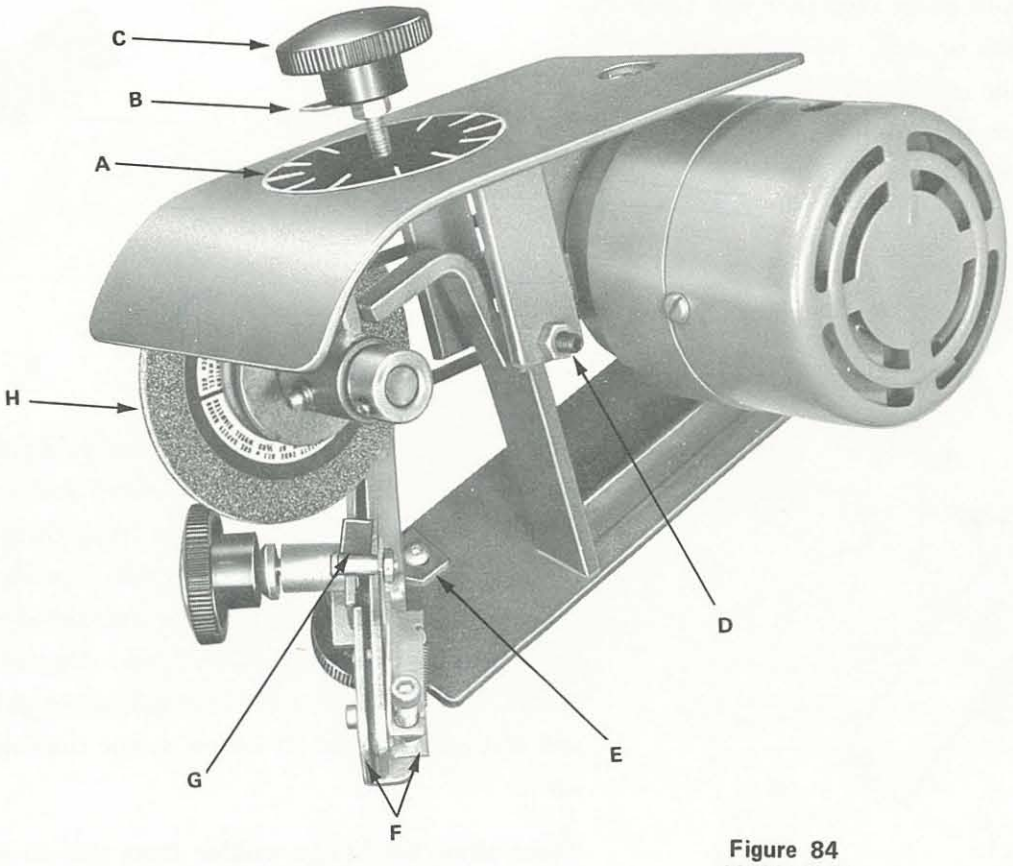


Figure 84

The depth control adjustment shown at C limits the amount of down travel of the grinding wheel. This depth control screw has a pointer shown at B that aligns with the circular scale shown at A. The scale is divided into twelve parts. Each graduation represents .005 inch. When the control knob C is turned the screw moves up and down limiting the amount of downward travel of the grinding wheel.

The entire motor assembly and grinding wheel is designed to pivot at point D. The stop at E is set to give the chain carrier assembly F the proper cutting angle. The carrier can be moved either right or left and the stop will permit the carrier to be positioned at the correct sharpening angle for all chipper cutters.

The pawl assembly shown at G is adjustable for cutter spacing of the chain cutters. The grinding wheel shown at H is 4-inch diameter and may be either 3/16 or 1/8 inch thick to sharpen most of the popular chains.

MODEL 550 CHAIN SAW GRINDER

Chain saw manufacturers stress three simple rules to follow in good saw chain maintenance:

1. *Keep it sharp*
2. *Keep it properly adjusted*
3. *Keep it well oiled*

To keep a saw chain properly sharp is the most difficult of these three. While the operator can file his own chain for a while, all manufacturers recommend it be sharpened on an electric grinder regularly so that the cutting tooth can be reshaped to the ORIGINAL FACTORY cutting angles and the depth gauge be lowered to insure maximum cutting performance.

With the few simple controls explained in the following instructions, you will accomplish precision sharpening that restores exact factory cutting angles. You will bring each cutter and depth gauge to uniform size, shape and true sharpness that assures fast, smooth cutting.

DRESSING GRINDING WHEELS

To properly shape the saw chain gullets, you must shape your grinding wheel to a round face as shown in Figure 85.

Use a dressing brick, dress the face of the wheel with the machine ON and the wheel turning. Rock the brick back and forth using light pressure until the corners of the wheel have been removed and the wheel rounded. It is important that this shape be maintained. From time to time during the sharpening of your saw chain, use the dressing brick on the grinding wheel. Not only does this allow you to maintain shape, but it also removes embedded metal from previous grindings so the wheel will cut cool and fast.

Figure 85

OPERATING THE MACHINE

1. Place the chain in the track of the chain support bar shown at A in Figure 86. Point cutters to the left. Swing the bar counter-clockwise until it hits the stop.

2. Select the shortest cutter on the OUTSIDE of the chain. Apply pressure against the pawl shown at B and adjust the feed screw C until the cutter just touches the grinding wheel. Clamp the position.

3. Adjust the depth screw, shown at D, to stop the downward travel of the grinding wheel at the gullet point. Loosen clamp bar. Grind every other tooth in this direction.

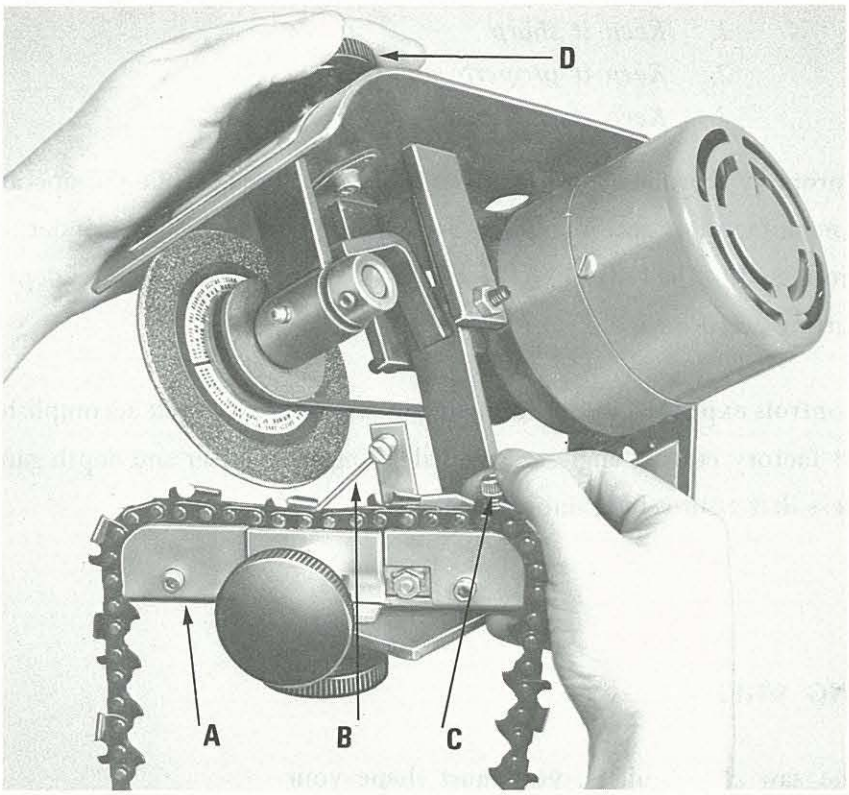


Figure 86

GRINDING CUTTERS

Hold the chain for light pressure of the tooth against the pawl B until it is in proper position. Then clamp the chain in position with the clamping knob. Tilt the wheel down slowly for light grind on the first tooth. Always avoid heavy grinding that can discolor a tooth or possibly take out its temper. When the chain is in such bad condition that between 1/16 inch and 1/8 inch metal must be removed, do it in several light passes, going around the chain several times, avoiding excessive heat. After sharpening all cutters on one side, swing the bar in the opposite direction to the stop and repeat on the cutters on the INSIDE of the chain.

TOP PLATE ANGLE

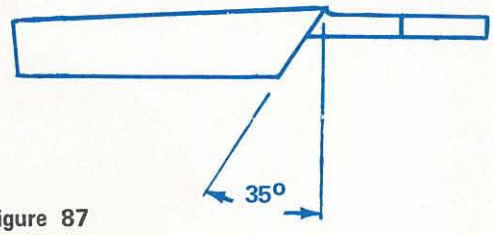


Figure 87

Shape of the stop automatically positions the bar at the proper 35-degree angle, as soon as the bar contacts it. If this angle is less than 35-degrees, then the side plate cutting edge will be blunt and the chain will not cut as fast. The greater angle produces a thin cutting edge that will dull too fast. Therefore, for all normal type of chains, this angle should be 35-degrees as shown in Figure 87.

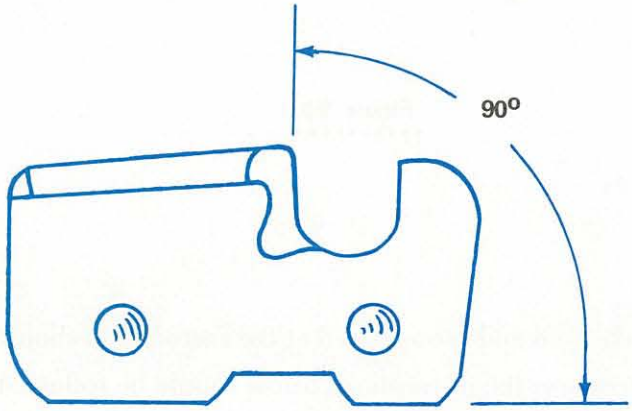


Figure 88

SIDE PLATE ANGLE

The side plate angle should be 90-degrees to bottom of the cutter. Adjustment of the feed screw and pawl assures this. The grinding wheel will extend into the gullet approximately 2/3 gullet depth. If the wheel goes deeper and the angle is more than 90-degrees the top plate will be feathered and dull faster. You may also grind the chain side link causing it to weaken. Grind at 90-degrees as shown in Figure 88.

If the cutting angle is negative, (slopes back), cutting will be slow because cutters tend to ride out of the cut and more pressure will be required to cut with the chain.

REMOVING ABRASIVE DAMAGE

When the saw chain has been damaged by abrasion or rocks as shown at A in Figure 89 it will not cut. The damaged part of the cutter must be ground out back to solid chrome as shown. Naturally, cutters must be sharpened more often under abrasive conditions as they will dull and wear away rapidly.

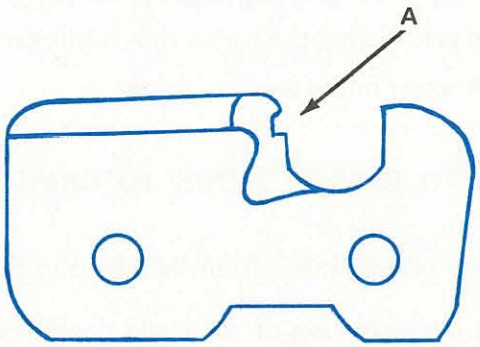


Figure 89

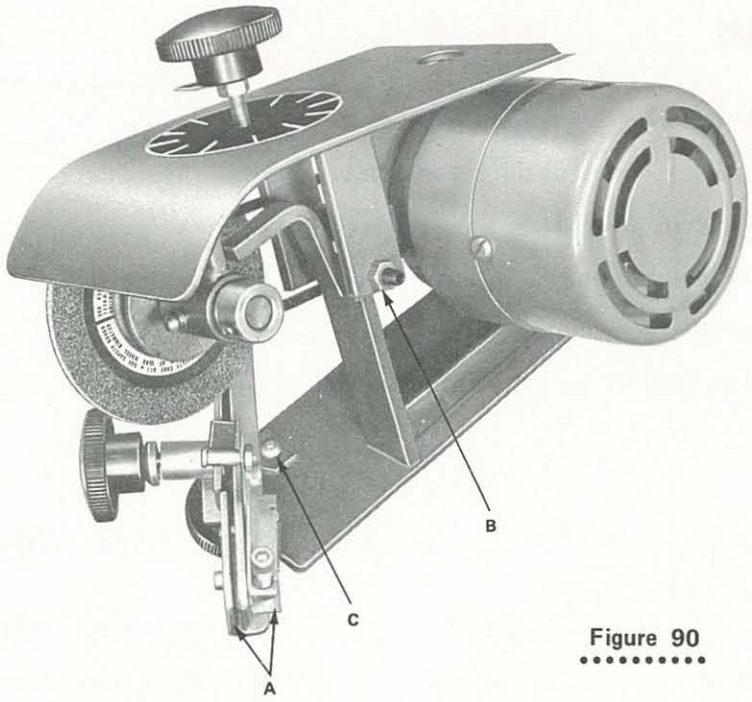


Figure 90

ADJUSTMENT

All Model 550 Chain Saw Grinders have been carefully checked and pre-adjusted at the factory and should require no further adjustment. If adjustment becomes necessary, the instructions below should be followed.

Note, if the cutters on one side of the chain are longer than the other, the right side of the grinding wheel is obviously not over the pivot point. In this case, mark the grinding wheel with a pencil. Prevent it from revolving and swing it down over the chain support bar shown at A in Figure 90. Swivel the bar and if the mark does not swivel on the pivot point, then the alignment of this unit has become out of adjustment. This is easily corrected by loosening the lock nuts shown at B on the cone point set screws. Move the wheel as needed by turning these cone point set screws, then retighten the nuts as required.

If the top plate grinding angle is not 35-degrees on each side, then loosen the set screw holding the stop shown at C. Swing the bar so that it hits each machined side equally. Once this is accomplished, retighten the set screw in the stop.

POINTS TO FOLLOW PRIOR TO GRINDING

1. Remove oil and pitch from the chain to prevent grinding wheel from glazing or gumming up.
2. Careful examination of the chain could prevent serious accidents to the customer. Therefore, check for worn or broken drive links. Check for bent or cracked links.
3. Check for tight pin joints.

DEPTH GAUGE CONTROL

The Depth Gauge Control shown in Figure 91 allows you to measure depth gauges to the exact factory specifications.

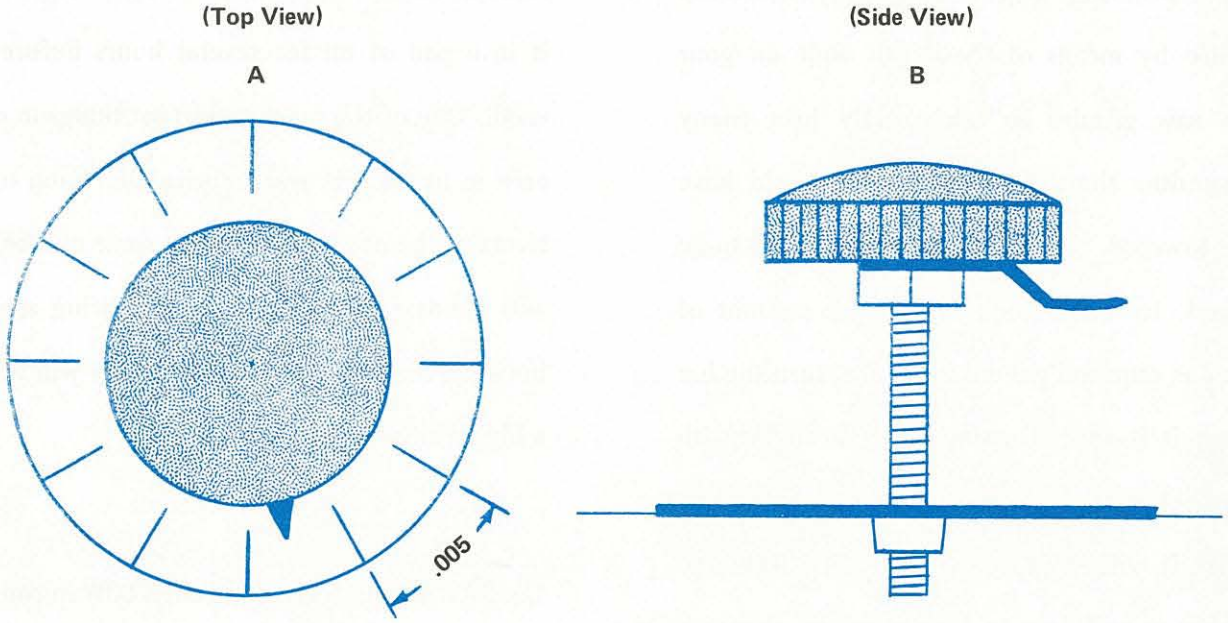


Figure 91

The dial gauge scale, shown at A is divided at .005 inch spacing. To allow accurate depth gauge setting, the grinding wheel is lowered so that it will just touch the top of the depth gauge. The wheel can then be lowered the proper distance by turning the knob B the correct number of spaces on the scale. (The distance between the marks represents .005"). To obtain the proper height for the depth raker, refer to the Grinding Depth Chart shown in Figure 92.

CHAIN PITCH	DEPTH GAUGE (SETTING)
1/4	.020 = 4 SPACES
.354	.025 = 5 SPACES
3/8	.025 = 5 SPACES
.404	.030 = 6 SPACES
7/16	.030 = 6 SPACES
1/2	.030 = 6 SPACES
9/16	.040 = 8 SPACES
5/8	.060 = 12 SPACES
3/4	.060 = 12 SPACES

Figure 92

The depth gauge on a chain is a very important function of that particular chain. They should be maintained to a uniform shape at all times. Not all depth gauges will have to be lowered. Before lowering depth gauges, you should measure by means of the depth scale on your chain saw grinder to see exactly how many thousandths that particular chain should have to be lowered. When the depth gauge has to be lowered, turn the knob the proper amount of spaces as required per table. (Also, turn the bar so that it is approximately at right angles with the wheel.) Flip the pawl over to the other side so that it will slide free in the slot. This also means you will have to loosen up the clamping device on your bar so that the chain can slide free. Grind the flat top of the first depth gauge by drawing the chain to the left under the wheel. Lift the wheel to clear the cutter and repeat around the chain. Then you should round off the leading edge by lifting the gauge from the slot in the bar and touching it lightly to the grinding wheel. By using rotating motions as it is grinding, you can keep the depth gauges to a uniform shape.

CHAIN LUBRICATION

New chains are coated with a rust preventative which is sometimes mistaken for a lubricant. Always clean a new chain in solvent and soak it in a pan of oil for several hours before it is used. One of the most important things in chain care is to keep it well lubricated. Each of the rivets in the chain operates the same as a bearing and needs plenty of oil. All bearing surfaces between the chain and the cutter bar will require a liberal amount of lubrication.

Use SAE 10W in winter and SAE 20W in summer. Never use crankcase oil, or used drain oil. Chain oil must be clean and fresh. Spare chains should be kept well oiled in plastic bags until they are ready to be used.

Oil the groove in the guide bar before installing the chain. While sawing, pump the chain oiler system often. Before oiling the chain it should be cleaned with a stiff bristle brush. Do not use a wire brush.

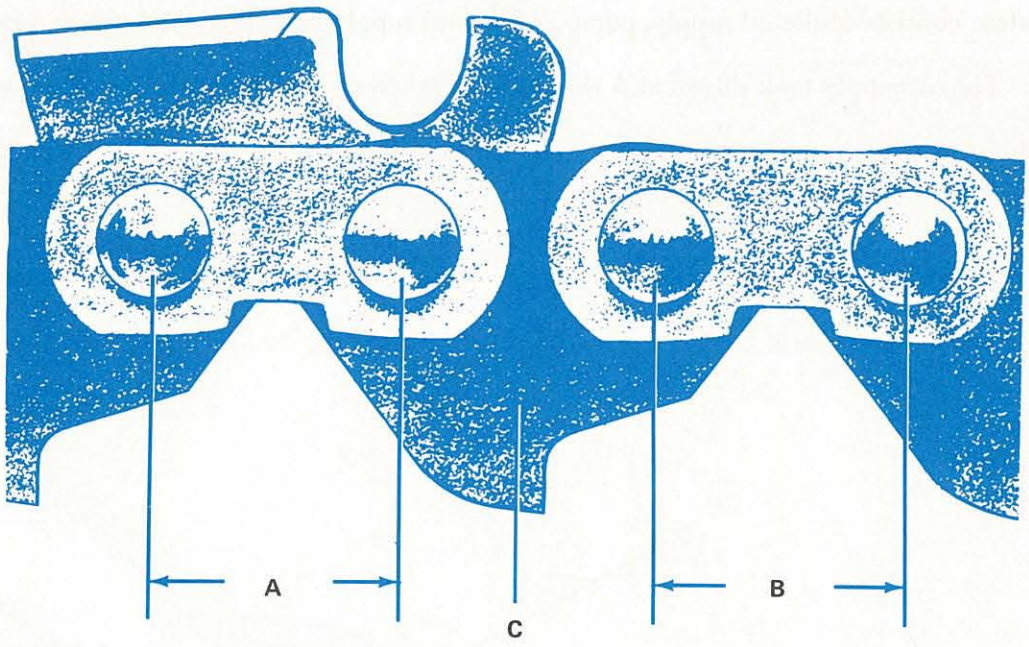


Figure 93

CHAIN OILER SYSTEM

Proper and adequate chain lubrication is one of the most important areas of maintenance to insure fast cutting and long chain life of both the chain and the guide bar.

Every chain saw is equipped with a manual operated oil pump to lubricate the chain and bar. This is usually a thumb operated pump located next to the throttle control trigger so it can be operated with the right hand. This conveniently located pump allows the operator to constantly oil the chain while using the saw.

Figure 93 shows the principle parts of the chain requiring lubrication. Both side links shown at A and B flex or turn like a bearing each time the chain goes around the nose or end of the bar. These four points function the same as a bearing and require considerable lubrication. The drive tang at C is riding in the groove of the bar. This metal against metal action can create considerable heat, due to friction, if an oil film is not present between the two surfaces.

Since many saw operators sometimes become absorbed in other aspects of sawing, such as watching for the saw to pinch and deciding which way the tree will fall, automatic oilers are now popular on most chain saws. These automatic oilers operate continuously when the engine is running. Often in heavy cutting, even though the automatic oiler is operating, it is necessary to supplement the chain and bar lubrication with the manual oiler system. Under normal conditions it is not necessary to use the manual oiler system very often.

The oiler system consists of the oil supply, pump, valves and supply line. Figure 94 shows a typical manual oiler system. The oil supply tank shown at A should be checked and refilled each time the engine is fueled. If the manual oiler is used extensively, as in very rough cutting, the oil supply should be checked more often.

The tank line shown at B is connected to the manual pump C. The oil line D carries lubrication from the pump to the guide bar and chain.

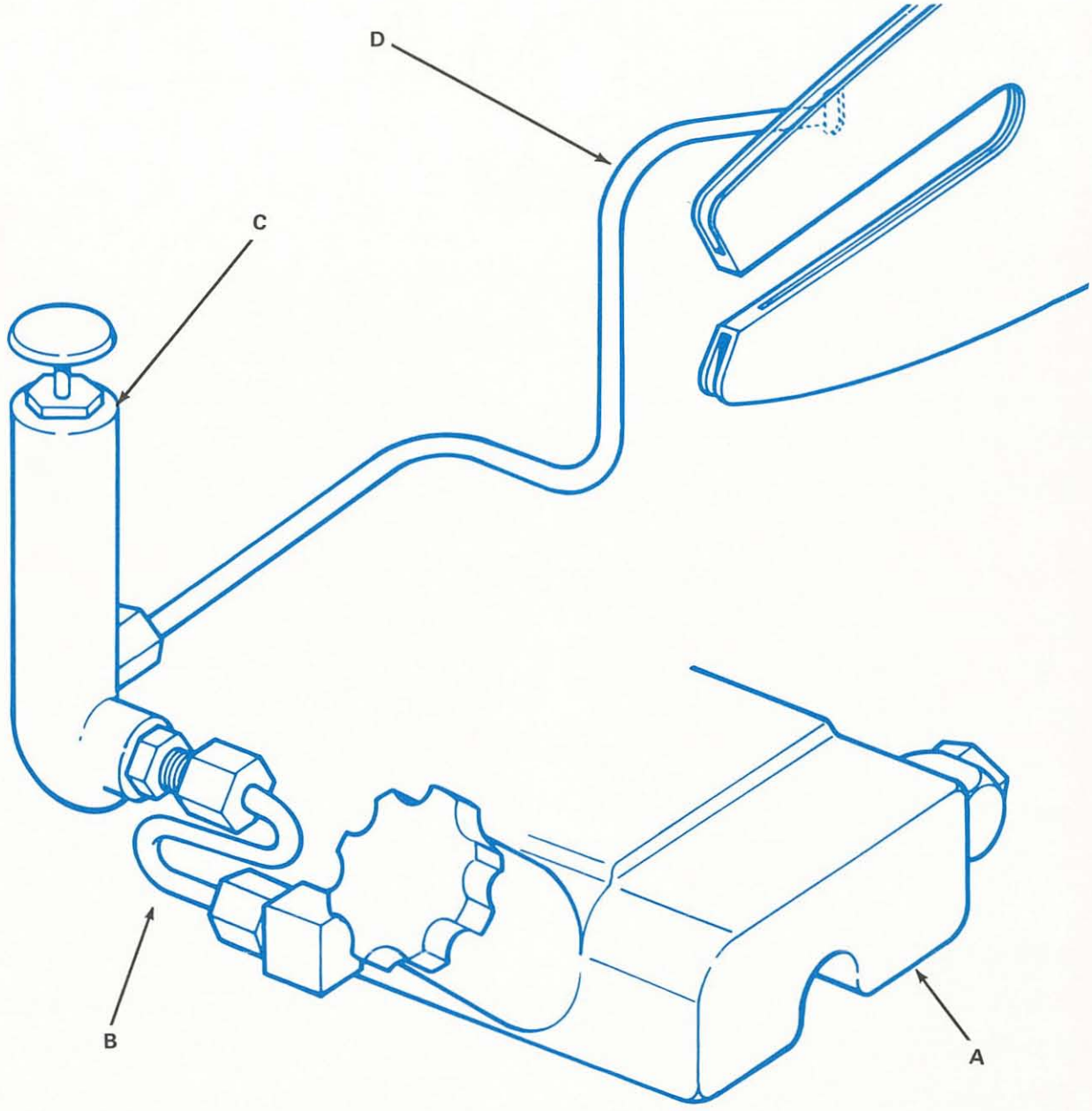


Figure 94

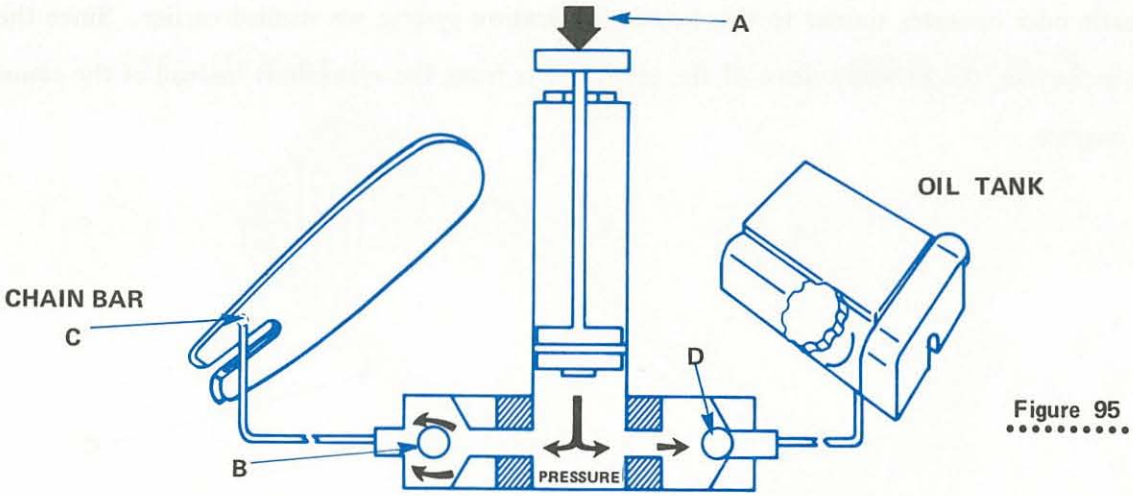


Figure 95

Figure 95 shows the basic operating principles of the manual oil pump. When the oiler button shown at A is pressed down it exerts pressure on the oil in the pump. There is a ball valve shown at B. When pressure is applied it opens the ball valve and forces oil through the line to the chain and guide bar at C. The same pressure that opens the ball valve B also closes the ball valve D. If this valve did not close oil would be forced back into the oil tank. Downward pressure of the oiler button exerts pressure to open valve B and at the same time closes valve D. After the oiler button is pressed all the way down the oil chamber in the pump is empty.

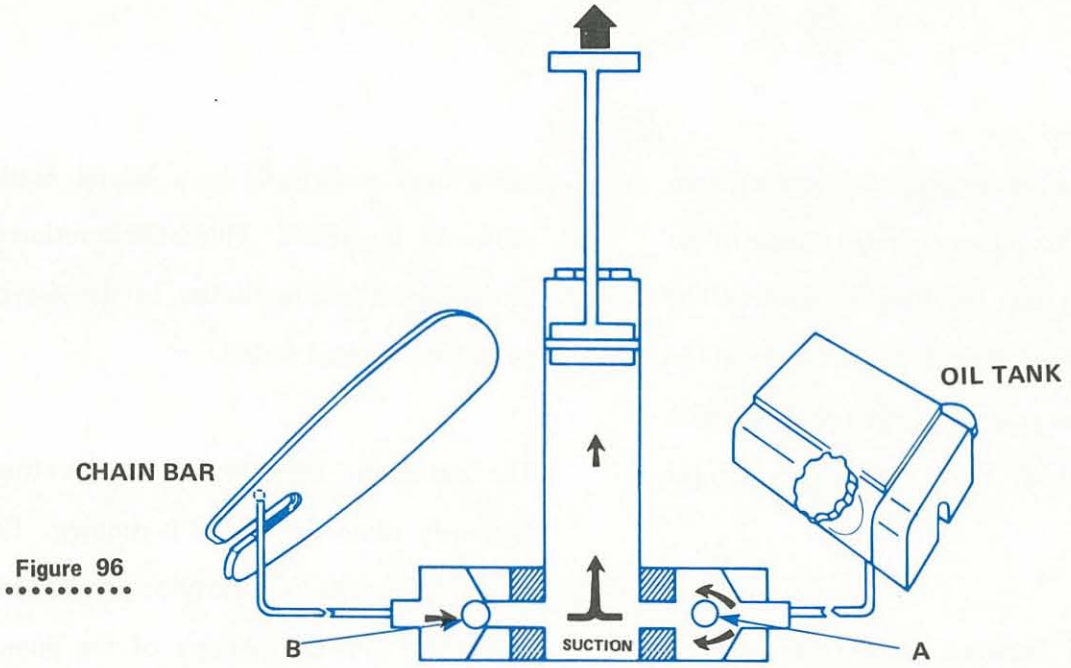


Figure 96

When the oiler button is released a spring will automatically force it back up as shown in Figure 96. When this happens it creates a negative pressure or suction inside the valve chamber. This suction opens the ball valve A coming from the tank and draws more oil into the valve chamber. When the oiler button is all the way up, the valve chamber is full. This same suction that opens valve A also closes valve B going to the chain and bar. When the oiler button is pushed down again the pressure on the oil then closes valve A and opens valve B the same as in Figure 95.

The automatic oiler operates similar to the 4-cycle lubrication system we studied earlier. Since the chain saw engine is 2-cycle, the primary drive of the oil pump is from the crankshaft instead of the camshaft as on 4-cycle engines.

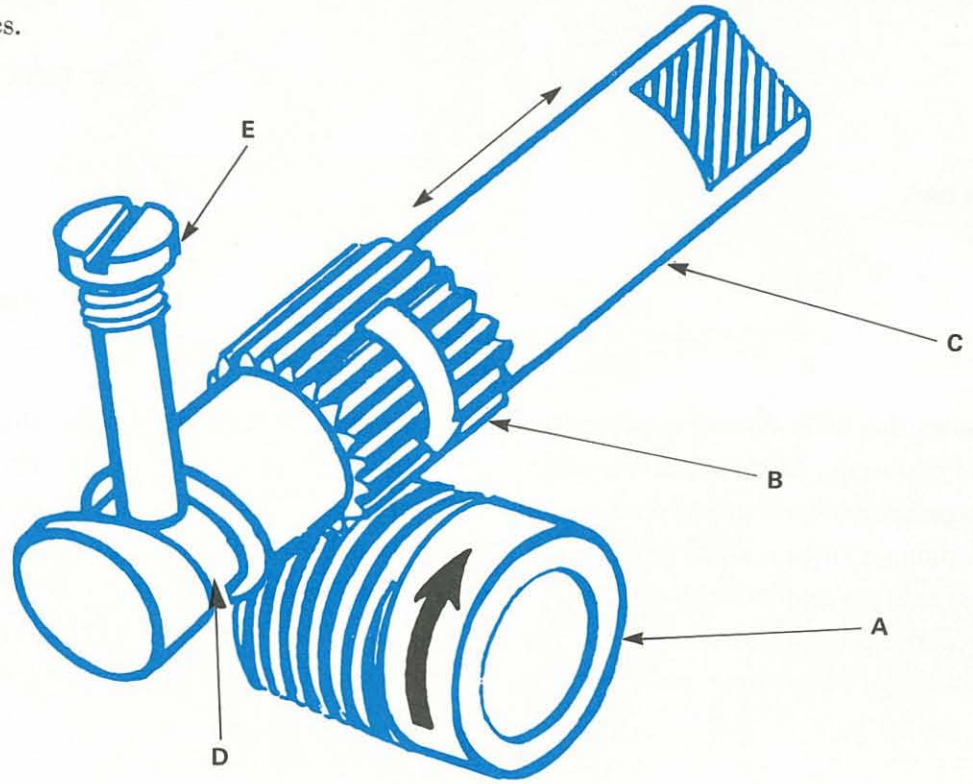


Figure 97

A typical chain saw automatic oil pump is shown in Figure 97. This pump operates similar to the plunger pump system on 4-cycle engines. The worm gear shown at A is driven direct from the crankshaft. This gear is engaged with the gear shown at B which turns the pump plunger shown at C.

The gear ratio between these two gears is designed so the driven gear B and pump plunger C is turning about 1/20 of the engine crankshaft speed. Notice there is a slot or groove milled at an angle in the plunger shaft at D. This groove engages the cam screw shown at E. As the shaft turns, this screw forces the plunger shaft C to move back and forth in a lateral motion as shown by the arrow. This lateral motion causes the pumping action similar to the 4-cycle oil pumps we covered earlier.

The automatic oiler system is operating continuously when the engine is running. Because of the high ratio of twenty-to-one between the crankshaft and the plunger of the pump very little oil flows while the engine is idling. When the engine comes up to its operating speed of about 2600 RPM, the oil stream increases to supply adequate lubrication to the chain and bar. The chain and drive links move the oil around the bar and groove.

The method of oil distribution to the chain and guide bar is shown in Figure 98. Some saws will have an automatic oiler hole as shown at A and manual oiler hole at B. Others may have a single hole located in the area shown at C. Oil from both the automatic and manual system will enter through the same hole.

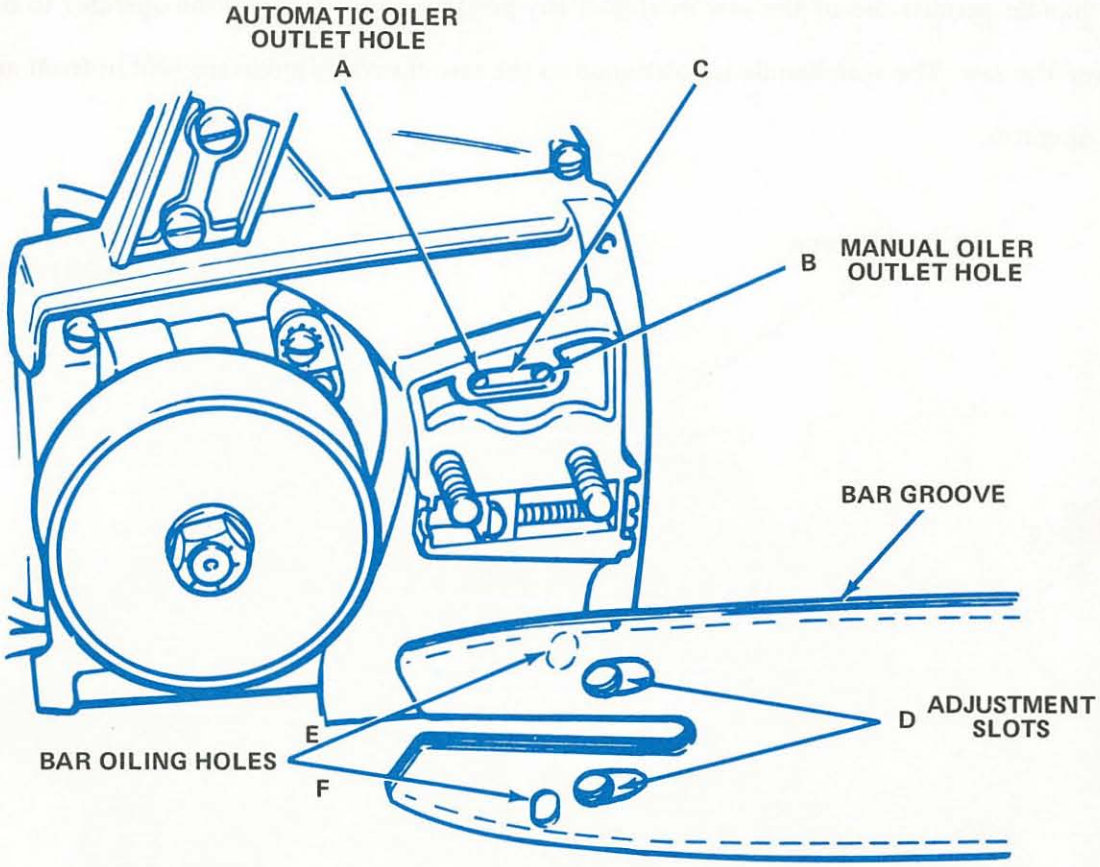


Figure 98

Notice, the bar has two slots in it shown at D. These are for tightening the chain and holding the bar to the saw frame. There are two more holes shown at E and F. They line up directly with the oiler outlet holes. These holes are made so they connect with the groove in the bar allowing oil to go into the bar groove.

When the bar is positioned as shown, the oil hole shown at E would feed oil to the bar groove. The guide bar should be turned over occasionally to distribute wear evenly around the bar. When the bar is turned over the oil hole shown at F is used for oil distribution.

PROTECTIVE DEVICES

The four basic protective devices used on most all chain saws are shown in Figure 99. By far, the most important are the front and rear handles shown at A and B. These are designed for the protection of the operator. The front handle is designed to make the saw safe and easy to handle in any position. The design of the handle permits use of the saw in almost any position and still allows the operator to have good control over the saw. The rear handle is positioned so the saw chain and guide are held in front and at one side of the operator.

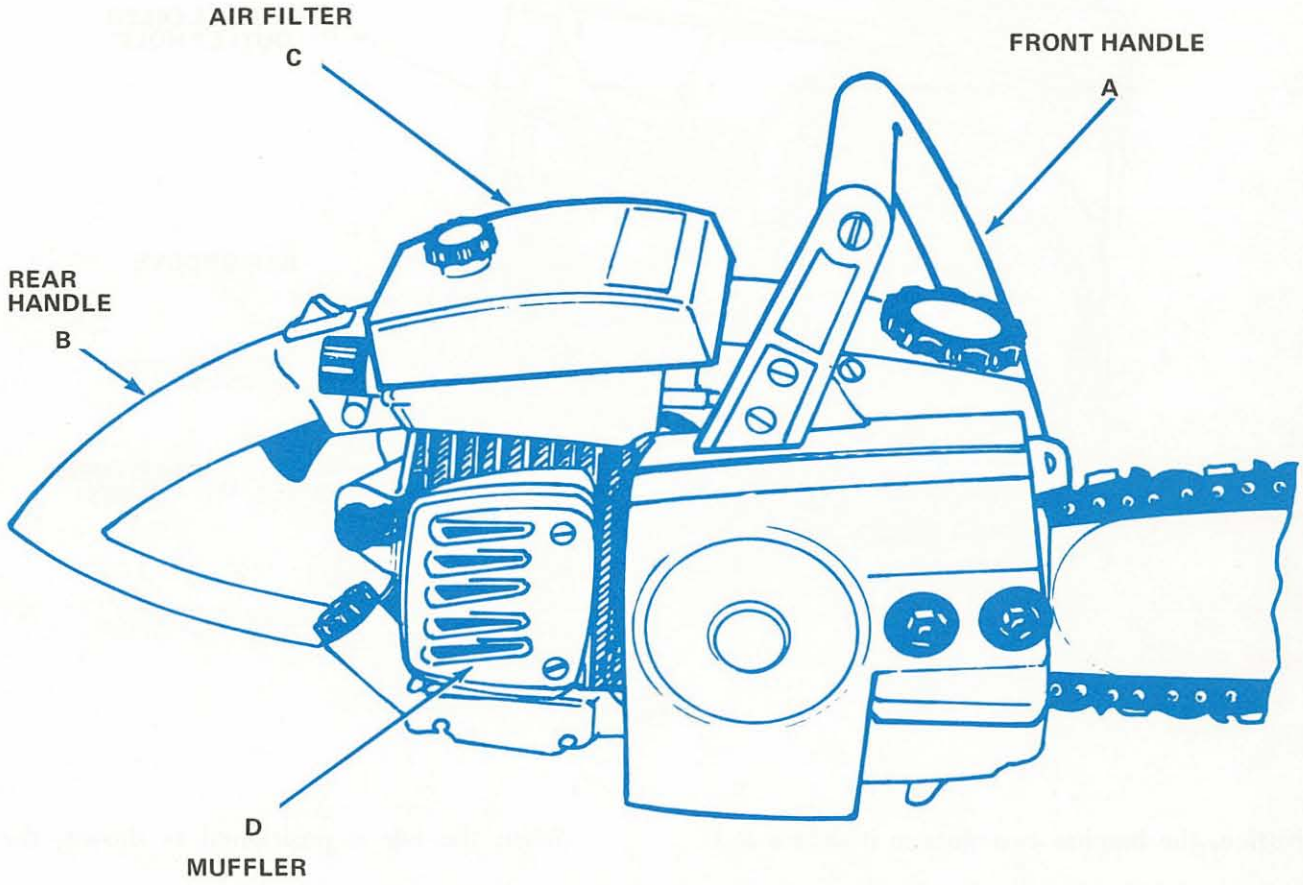


Figure 99

The air filter and muffler shown at C and D are necessary for the protection of the engine. No chain saw should ever be operated with any of these safety features missing or defective. It could easily cause injury to the operator or damage to the machine. A loose or broken handle could cause the saw to kick up and injure the operator. A defective muffler could cause a fire in the surrounding area.

MUFFLER AND FLAME ARRESTOR

The muffler on any engine has two basic functions. It must reduce flame coming out of the exhaust ports and it must reduce noise. Mufflers restrict the flow of the exhaust stream and in doing this they create back pressure in the combustion chamber of the cylinder. When the spark plug ignites the fuel/air mixture, an explosion occurs to force the piston down. The burnt gases must leave the combustion chamber through the exhaust. Any restriction as shown at A in Figure 100 will cause a back pressure and reduce the power of the engine. An efficient muffler will make the engine run quieter but it will also reduce power output.

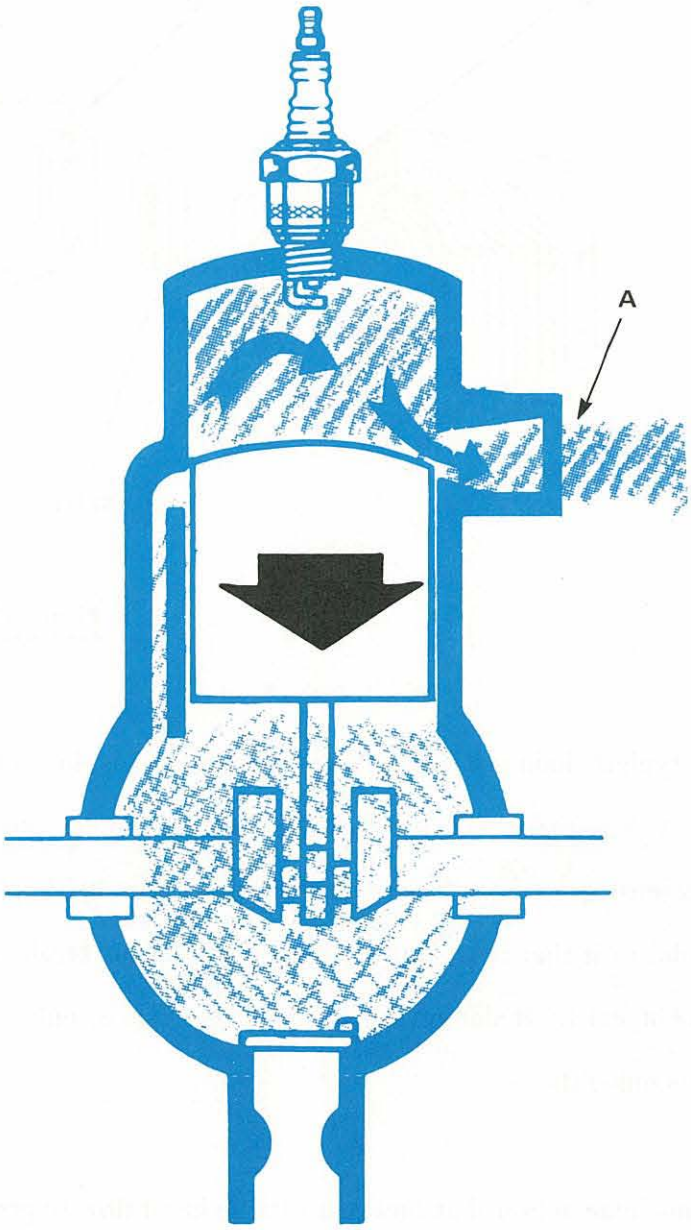


Figure 100

It is not practical to operate a small engine without a muffler because the noise would be too great for comfort and safety. The engine would also produce a solid sheet of flame out the exhaust. A compromise must be made on these small engines in order to reduce the noise to a tolerable level and break up the exhaust stream so it will not be a fire hazard.

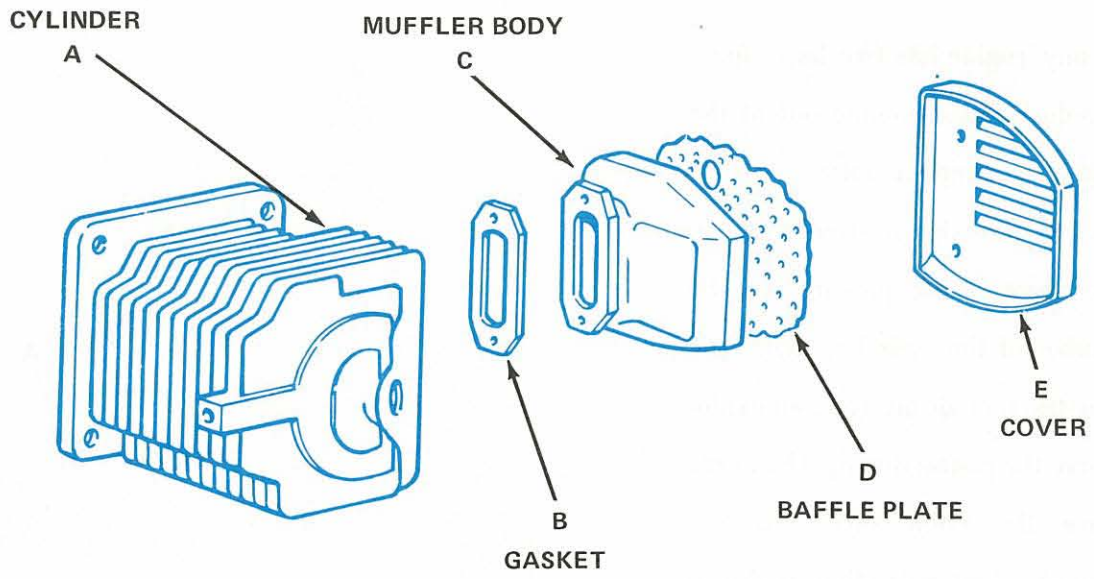


Figure 101

A typical chain saw muffler and flame arrestor is shown in Figure 101. The exhaust gases leave the cylinder at A. The gasket B is located between the cylinder and the muffler body C. This gasket makes a seal and prevents gases from leaking at this point. The baffle plate shown at D is a piece of metal with many small holes in it that restricts the exhaust flow. This breaks up the exhaust stream and deflects any flame that might exist. It doesn't break up all the flame, only a part of it. The cover shown at E breaks up any remaining flame.

This same action that breaks up the exhaust flow to prevent flames also breaks up the sound waves. These muffler and flame arrestor devices are designed to reduce the noise to a tolerable level and for safety and still not sacrifice too much power from the engine. The muffler design on lawnmowers and other small engines generally has a more efficient muffler system because the engines can be larger and afford more power loss. Since chain saws must be carried and used in many different positions they must be as light weight as possible and have maximum power per pound of engine weight.

AIR CLEANERS

The air cleaners used on most chain saws are different than most other small engines in that they are not attached direct to the air inlet side of the carburetor. The basic design of a typical air cleaner used on many chain saws is shown in Figure 102. The entire carburetor fits inside an air box. The air box shown at A receives clean air that has been drawn in through the filter B. Dust remains on the outside of the filter element and clean air is drawn into the carburetor C. The area shown at D contains clean filtered air ready to go into the carburetor intake.

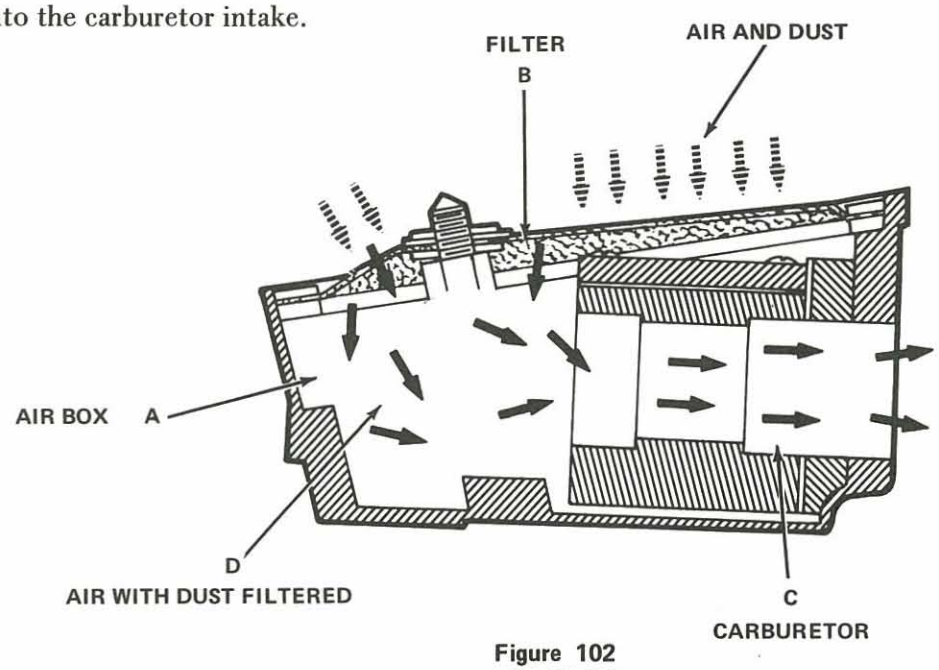
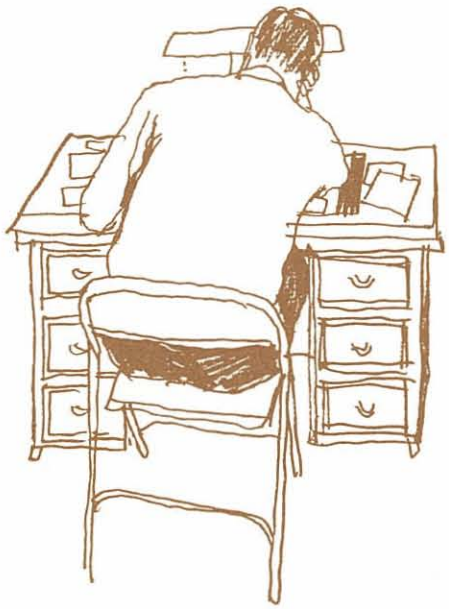


Figure 102

Air filters are generally made of a fine screen with some cloth filtering element attached to it. Air passes through leaving dust, dirt and sawdust on top of the filter which can be cleaned with most any solvent.

Since chain saw engines are 2-cycle engines, all maintenance, repair and service is the same as other 2-cycle engines. Their basic difference is in lighter weight and higher RPM. Because of the conditions these engines must operate under, they are more subject to damage and improper care. By following general 2-cycle service procedures you should have no difficulty keeping these engines in proper running condition.

This completes the study material for this lesson. Complete the examination that follows, along with the homework assignment sheet. Return the homework assignment sheet and **BOTH** examinations back to us for grading. Upon successful completion, you will then be awarded your Advanced Small Engine Diploma.



This completes the study material for this lesson....

. . . . and to earn a passing grade, you are now required to complete the Lesson Examination that follows and return it to us for grading.

Before you start on the Exam, we suggest that you read and review any subject that is not completely clear to you.

Before returning your completed Exam, Remember.....

. . . . to answer all questions. Incomplete answers will be scored Incorrect by your Instructor.

. . . . to fill out your name, address and Student Number exactly as they appear on our records. This information must be on the Exam.

After you have completed and returned the Exam to us for grading, proceed with the next lesson.

Student No.____-____-____
(Fill In)

LESSON NO.(S) _____ _____
(FILL IN)

(Leave Blank) GRADE(s)_____ _____

HOMEWORK ASSIGNMENT

STUDENT NOTE: *We can promptly grade your Examinations and keep you supplied with lessons if you will remember the following:*

- Please use the enclosed pre-addressed envelope to return your examinations.
- If more than one lesson has been completed, return no more than two examinations per envelope.
- For each envelope being returned, you need fill out only one Homework Assignment Sheet.
- In the space provided above, please fill in the numbers of the Lesson(s) that you are returning for grading.
- Installment Students: Please see Instruction No. 5 below.

(Fold Here)

INSTRUCTIONS:

1. Print (or type) your Name and Address in the spaces provided below.
2. Fill in your Student Number at top left corner of this sheet.
3. Enclose this Homework Assignment Sheet with your completed examination(s).
4. If you have any questions concerning this lesson, please list them on the special Quick-Reply Student Correspondence Letter and attach to this sheet.
5. If you are enrolled on our Monthly Payment plan, you may complete up to five lessons for each monthly payment made.

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NAME_____
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FINAL EXAMINATION
ON CHAIN SAW REPAIR

LESSON NO 44

FOLEY-BELSAW INSTITUTE OF SMALL ENGINE REPAIR
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NAME _____
PLEASE PRINT

ADDRESS _____

CITY-STATE-ZIP _____

Student No. _____

Date _____

INSTRUCTIONS:

(1) Fill in the information above, and the answers to all questions. Please type or print clearly.

(2) If you have any questions concerning this lesson, use the special Quick-Reply Student Correspondence forms provided. Please do not put questions or other correspondence on this Examination.

Examination questions for the Chain Saw Section of the Small Engines Repair. True & False, filling in the missing word and multiple choice type questions.

1. Chain saws generally use _____ cycle engines.

2. The clutch on a chain saw is attached directly to the _____.

3. Most chain saws recommend from _____ to _____ pint of SAE oil with each gallon of regular gasoline.

4. If the engine smokes excessively, you can reduce the oil mixture, but never below _____ per gallon.

5. Excessive binding of the blade will shorten the life of both the _____ and the _____.

6. A _____ is used between the engine crankshaft and the chain drive sprocket.

7. When the engine is idling, the clutch will drive the chain slow.
   ☐ True
   ☐ False

8. When the engine reaches _____ RPM, the clutch will engage and begin driving the chain drive sprocket.

9. The clutch shoes are attached directly to the _____.

10. The clutch shoes turn at all times the _____ is turning.

11. The _____ are designed so they will expand when the crankshaft reaches a speed of about 2600 RPM.

12. The _____ is attached directly to the sprocket.

13. Most chain saw clutches operate on the principle of _____ force.

14. Name the two basic types of drive sprockets used on most chain saws:
   A _____
   B _____

15. Chain pitch must be matched to the _____ pitch.

16. Too much pitch allows the driving links of the chain to ride too _____ on the teeth of the sprocket.

(Continued on page 2)

17. If the sprocket is too small, it will allow the drive links of the chain to ride up on the _____ of the sprocket.

18. The three basic parts that make up a saw chain are:

A _____

B _____

C _____

19. The three basic types of chain cutters generally used are:

A _____

B _____

C _____

20. Name the parts of the cutter shown in Figure 1.

A _____

B _____

C _____

D _____

E _____

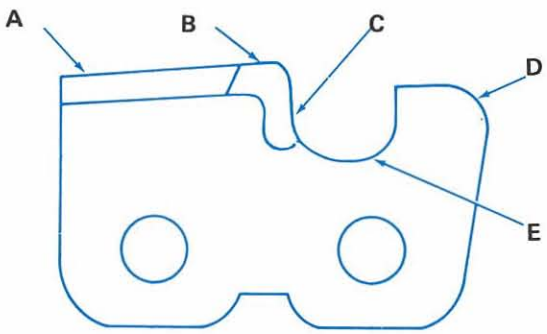

Figure 1

21. The _____ of a saw chain must be lower than the top cutting edge.

22. The amount of _____ on a saw chain will depend on the pitch of the chain and can be from .020 to .060 inch.

23. Chain pitch is the distance between the centers of three rivets.
☐ True
☐ False

24. Depth gauge settings are sometimes referred to as _____.

25. The _____ length cleans out the guide bar groove.

26. The top cutting angles for the three basic types of cutters are:

A _____

B _____

C _____

27. A saw chain will have a different tension when it is cold.
☐ True
☐ False

28. Cracks under the front rivet of cutters are caused by the depth gauge being too _____.

29. When sharpening cutters the file should be from _____ to _____ of its diameter above the cutter.

30. Name the size files used to sharpen the majority of saw chains:

A _____

B _____

31. The oiler system consists of:

A _____

B _____

C _____

32. The automatic oiler system is operating continuously when the engine is running.
☐ True
☐ False

(Continued on page 3)

33. The four basic protective devices used on most all chain saws are:

A _____

B _____

C _____

D _____

34. The muffler of an engine has two basic functions:

A _____

B _____